Forest inventory and management plans of

Bkessine and Andket forests in Lebanon

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Lebanon's National Blueprint for a Sustainable Forest Biomass: promoting renewable energy and forest stewardship

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Developed by:
Biodiversity Program
Institute of the Environment – University of Balamand – Lebanon

In partnership with:
The University of Lleida - Spain

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Credits

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Foreword

The "National Bioenergy Strategy for Lebanon", published by the Ministry of Energy and Water and the UNDP back in 2012, indicated that the most promising biomass resource for the country is that of sustainably harvested forestry and agricultural residues. The newly published National Renewable Energy Action Plan (NREAP) 2016 – 2020 has set a target of bioenergy for heating at 166.66 ktoe by 2020.

In order to reach these targets, we must support and monitor all stages of biomass production, ensuring first and foremost that the harvesting of biomass from forestry residues or from agricultural residues is done in a sustainable manner. It is also important to note that harvesting of biomass from forestry residues has the added benefits of reducing fire risks and creating rural employment, and harvesting of biomass from agricultural residues may increase revenues for farmers. We must make sure that the technologies that are set up to transform these residues are up to the required technical and environmental specifications.

The Ministry of Energy and Water is committed to focus not only on electricity production from bioenergy, but also on heating as well in order to increase our energy security and provide affordable and sustainable heating options for rural communities. At this stage, and thanks to the pilot projects implemented by the UNDP CEDRO, the country is gathering pace and momentum towards achieving a more sustainable energy system. We are moving forward to understand better the national and natural resources, which may be used to satisfy our growing energy needs.

Arthur Nazarian
Minister of Energy and Water

Foreword

The strategy of the Ministry of Agriculture for the years 2015–2019 included the objective of improving the good governance and sustainable use of natural resources through:

1) Adopting good governance and promoting sustainable use of forests, and;

2) Implementing Lebanon's forest fire management Strategy and rationalizing the harvest and investment of wood and non-wood forest products.

In addition to establishing an area of forests and rangelands on which a plan for sustainable management was foreseen.

Lebanon's National Strategy for forest fire management (Decision No. 52) comprised a strategic objective on modifying fire risk through a number of means (e.g., encouragement of sustainable fuel wood collection coupled with incentives for farmers/herders not to burn crop residue and pastures). Also, it addressed the need to develop preventive silviculture and fuel management aiming at reducing the highly flammable biomass and management of the forests to increase their resistance to fires (or reduce their susceptibility to fires). This includes but is not limited to grubbing and pruning, tree thinning, brushwood crushing, prescribed burning, controlled grazing and species selection.

Lebanon's National Forest Program (2015-2025) operational objective 5 highlighted the importance of developing an action plan to support small entrepreneurs and small forest enterprises through the development of value chains in wood (Activity 5.1) in addition to putting in place a sustainable management plan for the development of the socio-economic values of wood (Activity 5.3).

To this end, I hope that this publication will serve the purpose of further promoting the sustainable harvest and use of biomass from forestry and agricultural residues such that our forests are further protected from risks of fires and in order to increase local sources of employment and revenue.

Akram Chehayeb
Minister of Agriculture

Foreword

The European Union gladly contributed to this innovative project, which looked into biomass briquetting from forest residues in Lebanon. The project provided framework for both analysis and experimentation on this renewable energy source – which is still rarely used in the country. The strong leadership of the CEDRO IV project team and the Ministry of Energy and Water in this pilot operation has led to interesting and promising conclusions that are described in this report.

In the European Union we did similar exercises some years ago, and it was widely acknowledged that increasing the use of biomass in the EU could not only help diversify Europe's energy supply, but could also create substantial growth and jobs while lowering greenhouse gas emissions. We look forward to witnessing a sustainable development of this promising source of energy in Lebanon, and its direct and indirect positive effects on Lebanon' socio-economic situation.

Ambassador Christina Lassen

Head of the Delegation of the European Union to Lebanon

Foreword

The present set of reports on the potential use of bioenergy in Lebanon was prepared by the "Community Efficiency and Renewable Energy Demonstration" (CEDRO) project, which supports the country's efforts towards a national sustainable energy strategy. CEDRO, active in Lebanon since 2007, is funded by the European Union and implemented by UNDP.

Bioenergy which originates from forest and agricultural residues can be fabricated into various forms such as briquettes or logs, and has the potential to be a viable resource for household heating and cooking. Using bioenergy reduces dependence on highly polluting fossil fuels and also plays a vital role in reducing illegal logging. With the increasing risks of forest fires posed by climate change, establishing a value chain for the sustainable harvesting of forest residues for briquette production also serves to reduce this risk. Finally, the production of bioenergy provides sources of rural income to local communities and generates employment opportunities since manufacturing includes labour intensive tasks such as pruning of trees and collection of biomaterial.

Biomass briquette production has a significant growth potential both in residential and industrial markets. Its environmental benefits include sustainable forest management, neutral carbon dioxide emissions balance, and low sulphur emissions. Its other advantages include a high calorific fraction, significant moisture content, and lower ash content. In general, briquettes are an ideal fuel for low consumptions where the higher cost of the fuel is balanced out by the lower investment cost of the simplified heating technologies.

The reports are based on practical knowledge gained by the CEDRO project during the implementation of two pilot projects that introduced systems for briquette production. They provide real-life tools and guidelines on how to manage forest resources in the Lebanese context, how to design and construct briquetting machines, and how to manage the systems. UNDP hopes that these publications can support in expanding the use of such environmentally-friendly technologies and promoting the uptake of sustainable energy resources in Lebanon.

Philippe Lazzarini
UNDP Resident Representative

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List of Acronyms

ADELNORD	Projet d'Appui au Développement Local dans le Nord du Liban
AFDC	Association for Forest Development and Conservation
BA	Basal Area
BP	Biodiversity Program
CDR	Council for Development and Reconstruction
CEDRO	Country Energy efficiency and Renewable Energy Demonstration Project
DBH	Diameter at breast height
DEM	Digital Elevation Model
DC	Diametric Class
DRDNR	Directorate of Rural Development and Natural Resources
EU	European Union
FAO	Food and Agriculture Organization
FMP	Forest Management Plan
FRA	Forest Resources Assessment
GFA	GFA Consulting Group
GFI	General forest Inventory
GIS	Geographic Information System
H	Tree Height
IOE	Institute of the Environment
LBP	Lebanese Pound
LP	Land features, physiographic limits and infrastructures
LRI	Lebanon's Reforestation Initiative
LULC	Land Use Land Cover
MC	Moisture Content
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MU	Management Unit
NDVI	Normalized Differenced Vegetation Index
NGO	Non-Governmental Organization
NWFP	Non-Wood Forest Product
ONF	Office National des Forêts
OWL	Other Wooded Land
PACA	Provence- Alpes- Côtes d'Azur region of France
PAI	Periodic Annual Increment
PCHZone	Pine Cones Harvesting Zones
PT	Total Weight

R/NIR	Red/ Near Infrared
SC	Species composition
SI	Site index
SS	Stands of special interest
ST	Stand structure
TC	Tree cover
UNDP	United Nations Development Programme
UOB	University of Balamand
USAID	United States Agency for International Development
USD	United States Dollars
USFS	United States Forest Service
UTM	Universal Transverse Mercator

Executive Summary

The scope of work herein comprised the development for each of Bkessine's and Andket's forests' inventory and management plans. In specific, the work included the development of:

1. A Forest Inventory that is accurate enough to allow the classification of the study area in homogeneous units which will be the basis for planners to conduct the management plan
2. A Forest Management Plan (FMP) in conformity with Lebanon's forest policy, legislation and regulations, taking into account the international forest planning expertise, in similar ecologic conditions.
3. A Harvest Plan for each individual harvest area, based mainly on site inspections.
4. Accurate Forest Inventories for specific areas for exploitation of the FMP.

The development of a management plan comes in line with the Law No. 85 (1991) and the forest law materials issued in 1949. Since the Directorate of Rural Development and Natural Resources (DRDNR) at the Ministry of Agriculture (MOA) is in charge of the protection of forest wealth, it is the only party that can bring, accompany, and monitor the implementation of a forest management plan.

Bkessine's forest

In the case of Bkessine's forest, the Forest Inventory resulted in precise stand delimitation and identification of 18 Management Units (MU) with an average area of 12 ha. The MUs were visually characterized according to density, age, mean diameter, dominant height, volume and biomass. Errors committed in the estimation of volume at the MU level were well under 15%, which is the upper limit in productive forests in other Mediterranean countries (i.e. in Spain).

Subsequently, a Forest Management Plan (FMP) was developed for the Bkessine's forest to achieve a healthy and sustainable forest ecosystem which is vital for the well-being of Bkessine community. The plan included economic objectives such as the production of bioenergy and pine nuts in addition to social and environmental objectives, such as ecotourism and forest fire prevention activities. Accordingly, each unit of the MUs was assigned to one or several objectives according to their characteristics in addition to other criteria such as proximity to roads, and ecotourism potential among others. For the purpose of achieving the objectives of this assessment, several prescriptions were suggested per MU, and each prescription was related to a set of monitoring measures (indicators) and a prioritization of implementation actions as per previously specified objectives.

In the Harvest Plan, the general prescription for the forest in the next ten years was formulated around regeneration and tending of seedlings, pruning, thinning (high relative density areas in relation to their age) and other goal-specific treatments in certain management units (MU) due to recreational significance. Removal of trees with the intent of assisting natural regeneration is planned for, but in case the legal constraints are changed or new situations arise, harvest volume estimations were provided for each MU. Biomass products for the briquette plant were estimated from stone pine pruning conducted traditionally for the next ten years, pruning of Quercus sp., and thinning Pinus brutia trees. Since the forest was stated to be 15 years late in pruning requirements, and rotation for this treatment is estimated optimal every 7 to 10 years, the prescription for this treatment was designed to match temporally the planting.

Overall, the plan was to keep a "business as usual" forest management for the community, while introducing gradual changes over time. The required investment for pruning every year was estimated between 66.66 and 87.49 Million LBP (approx. 44,440 – 58,300 USD). This remains within the current budget available in the Reforestation Fund of the MOA (100 Million LBP or 66,600 USD, from former year auctions). An approximate 50% of the forest can be regenerated artificially under this scheme in ten years, requiring 5,000-9,000 trees produced at the nursery and planted per year (650 trees/ha, 4x4 m layout). As the nursery is capable of producing 40,000 seedlings per year, this should be feasible. The necessary investments in planting and tending have to be guaranteed.

The main challenge for this forest is primarily old age and lack of younger age classes, followed by other possible threats such as significant increase in tourism favored by the infrastructures being built. It is critical that the forest improves in age class distribution and diversity of species, as it is the best strategy for mitigation against unwanted changes. Improvements in the forest require that the Plan will be implemented through an agreement between the Municipality and MOA and with the involvement of experts in the field and the supervision of the forest guards of the Ministry. As some actions/recommendations in this Plan are controversial or downright illegal, acceptance by the relevant authorities is needed. Removing trees with low production and improving the tree growth/production in MUs with densities over 300 trees/ha, for example, may encounter legal or administrative barriers. The current legal framework in Lebanon prohibits trees cutting for promoting the growth of a young forest. This was considered as the main constraint to the rejuvenation of the forest. The rejuvenation of the stone pine forest in Bkessine is much needed.

Andket's forest

The forest in Andket was initially divided into 9 MUs. The areas of MUs varied between 124.56 ha and 285.25 ha. Nevertheless, no previous information on stand delimitation existed within the different MUs. Not all the forest is covered by trees (i.e. presence of rocky areas, agricultural lands, herbaceous pastures and shrublands without firewood or biomass potential). Tree stands occupy the forest in a patchy mosaic distribution, differing very notably in terms of silvicultural characteristics. The forest area is covered by different land use-land cover classes (LULCs) that have been classified in twelve categories. According to the potential management for biomass and firewood production, it was essential to discriminate between forested and non-forested areas, since non-forested areas do not currently contribute to biomass production. Non forested areas were excluded in the biomass and firewood estimations of the forest. The work focused on forested areas but in some cases (i.e. herbaceous pastures), non-forested areas could be afforested, and therefore, positively contributing to medium-term biomass production of the forest. Within the forested areas, there was a need to conduct a second sub-division in which the different tree stands should be identified. Stand delimitation was a necessary step for forest management. The aim of the forest stand delimitation was the definition of the minimum inventory and management unit areas presenting homogeneous silvicultural characteristics related to specific goals (i.e. biomass production). After stand delimitation, the surface covered by the main LULC classes and the extent of the five forest typologies in nine different MUs were estimated. The spatial layout distribution of these typologies suggested a past history of fires burning the landscape in a patchy pattern that creates age differences and even-aged or uneven-aged structures, depending on fire intensity and fire frequency. Regeneration does not appear difficult in general, but recently burned areas (i.e. during 2007, 2012 years) do not show signs of Pinus brutia regeneration. This could be due to high fire frequency and a high fire severity. Errors

committed in the estimation of volume at the LULC level were well under 30%, which is the upper limit in protective forests in other Mediterranean countries (e.g. Spain).

The objectives of the Forest Management Plan for Andket Forest needed to ensure an improved forest structure and productivity. The goals included avoiding the loss and the anticipated irreversible degradation of additional areas of the forest, ensuring the improvement of its health, and supplying fuelwood for local communities and biomass for bioenergy production. As a result, the forest would be strengthened to fulfill short to long term economic, ecological and social functions. In this context, the Forest Management Plan was structured into three categories: production of wood, conservation and protection, and recreational services. The LULC types of forest stands in each management unit were identified and classified according to their density, average height, volume, and biomass quantities. Each unit of the MUs was assigned to one or several objectives according to their characteristics in addition to other criteria such as proximity to roads, and ecotourism potential among others. For the purpose of achieving the objectives of this assessment, several prescriptions were suggested per MU and each prescription was related to a set of monitoring measures (indicators) and a priority for implementation. A detailed work plan for managing the biomass in MUs was presented.

Topography coupled with access was the principal consideration in defining harvesting blocks for the next planning period (2016-2025). However, as a consequence of the fact that, currently only biomass from stands in the 20-50 m buffer area around the few existing forest roads can be harvested, only a very minor part of the total standing biomass could be extracted. Three years were considered as sufficient to harvest the accessible stands with the higher stocking measured. This operationally reduced the planning period to three years. The generally medium to good productive conditions in the mid-lower slopes of the forest suggest that an 80-year maximum rotation may be conducive to optimum yield, which would require regeneration of 17 ha/year, or around 170 ha in a planning period of ten years (1640 ha/80 years). Entry of the forest in pole stage (i.e. in the early stages of thinning) would mark the start of thinning for a 20-year period, to achieve timber stage and full productive capacity around 40 years from start of regeneration. The years 40 and 60 after start of regeneration are suggested for the next thinning treatments. Thinning at this stage may focus in releasing selected trees from competition (125-200 future trees/ha) in a circular area of influence (a few m^2). Felling should be carried out through a uniform pattern designed to open gaps of sufficient dimension for regeneration. After this period, young plants (0-20 years-old) share regeneration units with remaining seed trees (10-20 trees/ha). These mature trees can be removed in the next 15-20 years when the first intervention of the next thinning sequence takes place (helping to make the first thinning more profitable). As observed in the field, there is a general lack of natural regeneration after fires at least in the North. Accordingly, it is proposed to plant in areas within MUs identified as requiring urgent planting: areas with recent fires, located in the central or core burned area (difficult to regenerate naturally for lack of seeds in close vicinities). In this context, a forest logbook and use of a Geographic Information System can help registering and monitoring the different requirements within each MU.

The main technical constraint for forest harvesting in Andket is accessibility to the forest. A forest road network should be discussed, argued (i.e. in terms of ecological and socio-economic constraints), and implemented (if agreed on) in a separate project according to the recommendations and terrain volume estimations and priorities that were provided herein.

1 Introduction

Contextual framework

This report comes within the framework of the technical proposal, herein called the Project, for "provision of professional services for the Inventory Development, Management Plans for Two Forests in Lebanon" submitted in response to "LEB/CO RFP/122/14".

The general objective of the Project is to evaluate the capacity of the municipal forest of Bkessine (about 200 ha) and Andket (about 1200 ha) to provide biomass for heating purposes, in a sustainable, well planned and prioritized manner, and inclusive of the main traditional and new uses of these forests and the surrounding rural areas.

The specific objectives of the Project are to develop:

- Forest inventories for the forests of Bkessine and Andket
- Ten-year management plan for each forest
- Ten-year harvesting plan for each of the units of intervention assigned annually
- Lessons learned and recommendations
- Blueprint for forest management in Lebanon, with particular attention to bioenergy

Scope of work

The scope of work herein comprised the development for each of Bkessine's and Andket's forests' inventory and management plans. In specific, the work includes:

1. A Forest Inventory that is accurate enough to allow the classification of the study area in homogeneous units which will be the basis for planners to conduct the management plan
2. A Forest Management Plan (FMP) in conformity with Lebanon's forest policy, legislation and regulations, taking into account the international forest planning expertise, in similar ecologic conditions
3. A Harvest Plan for each individual harvest area, based mainly on site inspections
4. Accurate Forest Inventories for specific areas for exploitation of the FMP

The National context

Forests cover about 137,000 ha (13% of the territory) and Other Wooded Land (OWL)[1] covers 106,000 ha (about 10%) of the Lebanese territory (FAO 2010, MOE/UNDP/ECODIT, 2011). Ownership of forested lands is almost equally distributed between the private and public sectors and religious orders (Mitri and El Hajj 2008).

between sea level and 1500 m, particularly in the Metn, Baabda, and Bkessine areas. Other types of pine forests are located at middle elevation where Calabrian Pine forests (Pinus brutia) occupy a

[1] *Forest: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Other wooded land: Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use. (FAO, 2010)*

large area in the North (e.g. Andket), and Aleppo Pine forests (Pinus halepensis) extend over an area of 400-500 ha in the southern part of the country.

Lebanon has two forest laws, namely the Forest Code of 1949 that provides the basis for the management of forests by the Ministry of Agriculture, and the Law 85 for the protection of forests (amended by law 558 in 1996). In addition, Lebanon adopted in 2009 a National Strategy for forest fire management (Decision 52 dated 13/5/2009).

The Ministry of Agriculture's (MOA) Directorate of Rural Development and Natural Resources (DRDNR) enforces forest legislation and apprehends offenders. The MOA reviewed some aspects of the forest legislation and cancelled the ban on the production of charcoal to allow a controlled exploitation and stop illegal felling (FAO 2005). This decision was also motivated by the need to reduce the build-up of highly flammable biomass, and alleviate poverty. It may also prevent acts of arson initiated to circumvent the ban on charcoal extraction. The DRDNR has also examined the feasibility of decentralizing forest management, up to a certain degree. Decentralization will lead to a higher involvement of local community groups, municipalities and grassroots organizations. However, such a measure can only be implemented after building the capacities of targeted stakeholders and raising awareness of targeted communities and populations.

Today, harvesting forests is not allowed in Lebanon except for broadleaved species such as Quercus infectoria and Quercus calliprinos for charcoal production and for wood fuel production. It is worth noting that law enforcement is weak. It is estimated that 60% of wood cutting activities are not recorded. This percentage differs depending on the caza, geographical specificities and consequently on the type of trees (UNDP/CEDRO 2012). Simultaneously, pruning of forest is allowed (but is not yet developed) only through a forest management plan considering sustainable harvesting and providing a sustainable resource for bioenergy production. Accordingly, "sustainable harvesting plans" and legislative changes are required (UNDP/CEDRO 2012).

In reference to the National Bioenergy Strategy for Lebanon (UNDP/CEDRO 2012), forest wood biomass stream presents an interesting theoretical potential. However, this potential is difficult to develop for several reasons: forests are located in the mountains where the first preoccupations are reforestation and biodiversity protection. Also, "sustainable harvesting" is difficult to establish as there is weak law enforcement in terms of cutting permit volumes and geographic distribution for broad leave species. It is estimated that the total primary energy potential of woody biomass and fellings ranges between 1952 and 2510 TJ/year, which is a relatively significant amount.

Until present, Lebanon lacks a National Forest Policy (NFP). It was supposed that forestry legislation would be reviewed for 2010-2020 with the implementation of the national forest plan. At this stage, Law 85 prohibits cutting in all conifer forests, including pine forests, which in majority, are state forests, easily exploitable for bioenergy production. Efforts have been deployed by NGOs, in collaboration with MOA to reactivating management rights in public land.

As stated in the publication "State of Lebanon's Forest 2007" (Mitri and El Hajj, 2008), the main threats to the Lebanese forests include fires, insects and diseases, urban expansion and changes in land use, quarries, wars, among other factors (Mitri et al. 2014). The combination of all these threats, in addition to natural environmental conditions, is resulting in overall forest degradation. Overall, sustainable forest management and its main tool -extraction of fellings from the forest- has numerous benefits to the forest. These may range from ecological goals such as target reconstruction ecosystem composition in flora and fauna, limiting forest fire risk, or promoting a healthy forested ecosystem, to socioeconomic goals related to the improvement of the living tree component of the standing volume (growing stock), landscape design, or raised production of non-wood forest products, among many others.

General guidelines for forest management planning

According to FAO (1977, 1993, 1995, and 1996) planning is an active process requiring careful thought about what could or should happen in the future and involves the coordination of all relevant activities for the purpose of achieving specified goals and objectives. Planning is an integral component of forest management; is about determining and expressing the goals and objectives which government, rural communities or companies have, and for deciding the targets and steps that should be taken in order to achieve those objectives.

There is no need to develop a complicated process of planning but it is essential to have clear objectives which a government and/or another party aims to achieve. Accordingly, an element of flexibility is desirable and necessary in order to cope with unforeseen events which could affect the achievement of the objectives. In general, forest management plans should have a minimum duration, or length, of 10 years. A shorter period than 10 years does not provide the medium-term stability that is needed to guide consistent implementation of sustainable forest management activities.

A review of relevant laws, regulations, and strategies

The National forest Law, decrees, ministerial decisions, and Lebanon's National strategy for forest fire management addressed various legal and strategic aspects in relation to managing municipal forests and forest fuel in general. Below is a review of relevant articles and items.

Forest Law issued (January 7, 1949)[2]

Article 1 – A forest means a land containing different trees, of big or small sizes, swirling on each other, or bush containing small trees not locked together, of kind that is generally used only for industry and fuel.

Article 11 – The Rural Development and Natural Resources Directorate (RDNRD) puts a system for forest investment ensuring its simultaneous exploitation, improvement, and continuous reforestation. The system is ratified by the Minister of Agriculture.

[2] *Unofficial translation from Arabic*

Article 54 - The forests that are owned entirely by villages are managed by municipalities to which they belong. Otherwise, they would be managed by village committees according to a special organizational arrangement placed by decree.

Divisions of any sort on the ownership of these forests are not allowed to be carried out among the population of the village.

Article 55 – Mayors or village committees appoint specialized forest guards at their own expenses to maintain their forests, and such appointments will be effective only after the authentication of RDNRD.

The RDNRD can terminate the appointments of those guards or it can isolate them.

Article 56 – The specialized forest guards are empowered with the same powers and functions of the public forest guards.

Article 57 – It is not possible to invest in the forests of the villages except in accordance with their regulations for investment. Each investment must obtain, in advance, permission from the RDNRD whether to cut trees, pick up fruits, or grazing among others.

Authorization must not be granted for cutting trees at ground level. An authorization will be granted by a decree only under compelling circumstances.

Also, it is not possible to transfer, store, and trade products from forests of municipalities and villages except in accordance with the provisions of Articles 33, 34, 35, 36 and 37.

Article 58 - The Municipal Council or the village Committee will be in charge of directly investing in the forest or through concessions after the approval of the RDNRD and in accordance with its prescribed conditions.

The provisions of Articles 19 and 20 are applied to mayors, and village committees.

Article 59 – The villages may not break the cadastral boundaries of their belonging forests without a special license through a decree based on an investigation carried out by the RDNRD.

Breaking a cadastral boundary is considered, by virtue, any illegal investment, extraction of trees, or permanent grazing of new spring spot in newly cut forests.

Article 60 – The RDNDR or its employees do not charge municipalities and villages compensation for carrying out prosecutions in relation to their forests and for any other work in relation to monitoring and management, and putting investment plans.

In the absence of communal lands subject to afforestation in the village, the communal body has the right to use this third in buying a barren land for afforestation.

Article 62 - The distribution of some forest products among the people of the village takes place according to custom and habit unless there is a contradicting instrument.

The municipal council or village committee is in charge of this task for distribution. The municipal council of the village committee will have to decide whether selling the products for the benefit of the town and the village rather than distributing them among the population of the village.

Article 63 - If the forest village was associated to rights of forest utilization independent of the right of investment for the town or village, these rights are identified and used in accordance with the provisions of Part II of the Law.

The provisions of Articles 38, 39, 40 and 41 which are competent with overviewing cutting sites are applied to the forests of municipalities and villages.

Article 93 – It is prohibited to cut trees of stone pine, Aleppo pine, Grecian juniper, Cedars of Lebanon, Cilician fir and other resinous trees from privately owned forests and from communal and public forests except by technical thinning. A thinning license will not be given except for an individual holder of a certificate from the RDNRD signed by the Minister of Agriculture and proving his/her afforestation of an area equivalent to two thousand square meters for each fifty trees of the type that is desired to be cut.

Article 96 – Individuals owning a barren land or an abandoned forest land should start reforesting that land throughout one year from the notice date of the MOA minister's decision in this respect and complete the reforestation works within three years.

Article 97 – In case the landowner does not undertake any work of the required reforestation within the period set in the previous Article, the State has the right to acquire the land and sell it in auction to be then reforested according to the previous Article.

Article 100 - If extraction of building materials and or cutting trees from forest lands are required by Public Works, then the Ministry of Public Works will indicate to the RDNRD the extraction and cutting areas before proceeding with the work.

The RDNRD in agreement with the terms set by the Ministry of Public Works and Transport will determine the conditions for extracting materials and cutting trees while conserving the forest. The RDNRD will determine, when necessary, the appropriate compensation to be paid to the State for working the land, and for the value of extracted material.

Article 101 – It is prohibited to set and transfer a fire outside the housing and buildings for investment within the forests boundaries as well as outside these forests within less than two hundred meters from the border in question.
This prohibition applies from July 1 to October 31, and it also applies to private forest owners and it includes the production of coal, tar and gum distillation, and in general all industries that require the

use of fire, taking into account the provisions of Articles 102, 103, 104 and 105.

Article 106 - No one is allowed to burn thorns, grass, straw and other plants, unless having a license from the RDNRD, on lands located less than five hundred meters from the forest and for the period extending from July 1 to October 31, and on lands located less than two hundred meters from November 1 to June 30, unless otherwise permitted.

Article 110 – It is not possible to establish any industrial enterprise that uses fire or has to establish a repository of fuel inside the forest or on a land of less than two hundred meters from the border of the forest without acquiring a license from the RDNRD.

Decree No. 1576 on April 5, 1950[3]

Article 23 – Communal Forest investment works are organized with the purpose of promoting the growth of trees until it reaches the largest size possible and subject to the provisions of Article 57 of the Forest Law.

Article 26 – It is possible to sell out forest products or lease pasture communal land only through public auction or by sealed envelope after the approval of the Ministry of Agriculture, etc.

Law to preserve the forest and forest wealth No. 85 dated September 7, 1991

With the absence of adequate control starting 1975, Lebanon's forests have been exposed to various types of abuse and infringement, leading to the enactment of Law No. 58 on the date of September 7, 1991.

Article I – It is forbidden to cut and manufacture all resin type of trees including Stone pine, Aleppo pine, Cedar of Lebanon, Cilician fir, Grecian juniper, cypress, and all other existing resinous trees within the forest owned by the State, the municipalities and villages, or individuals, etc. Public work projects conducted by the public institutions and licensed construction projects are exempted.

Working with Article 93 of the Forest Law is suspended.

Decision Number 4331/1 dated 30/8/2010[4]

The Minister of Agriculture signed a Decision bearing the number 433/1 and dated 30/8/2010 in respect of "regulating forest and other wooded land harvesting". According to the text of the Decision, the following was decided among others:

Article One: allows maintenance or investment in forests according to the following:

(a) General conditions of pruning and thinning:

[3] *Unofficial translation from Arabic*

[4] *Unofficial translation from Arabic*

1. Pruning is allowed from September 15 to April 15 of each year, and requests for pruning shall be received in the forest centers of MOA from July 1 to February 15 of each year.
2. The duration of daily work for investment works and transport is set from sunrise until sunset (work at night is forbidden).
3. It is strictly forbidden of introducing livestock grazing within the limits of sections invested for ten years.
4. Cutting a one-trunk tree is forbidden.
5. Pruning is allowed according to the following conditions: the removal of some twigs and branches:
   - Removal of curved branches and saving of three branches in every shrub given that the diameter of the branch is not less than 7 centimeters
   - Branches of one-trunk trees are pruned up to a maximum of one third of the height of trees
6. Shrubs are allowed to be thinned according to the following conditions:
   - If the slope gradient is between 40 and 50%: you should always hold on to at least sixty shrubs per dunum (i.e. 1000 m2) to be distributed uniformly over the entire property.
   - If the slope gradient is between 15% and 40%: you should always keep at least fifty shrubs per dunum to be distributed uniformly over the entire property.
   - If the slope gradient is less than 15%: you should always hold on to at least forty shrubs per dunum to be distributed uniformly over the entire property.
7. The forest ground should be cleaned from all twigs and branches resulting from the work process to prevent fires, and so on at least twenty meters from roads and buildings.
8. Fuelwood is transported according to specific permits issued by the competent forestry centers of MOA.
9. Fire sources and ignition are forbidden within the limits of forests and a distance of less than two hundred meters from the limits of forests and inhabited places.

Note: These conditions are considered an integral part of the license and every violation of the above mentioned conditions makes its perpetrator subjected to prosecution jointly with the property owner.

Article three: (a) It is allowed to cut off or break trees that hinder the reclamation of abandoned farmlands in accordance with the following conditions:

1. The forest cover should be below the 30% of the total property area.
2. The slope gradient should be below 40%.
3. The trees subject of cutting should be broadleaf trees only.
4. The acquisition of the Green Plan's approval (if the reclamation project is on the account of the Green Plan).
5. Provide a pledge at the notary to re-plant not later than 6 months from the date of issuance of the permit with determining a penalty clause in the pledge at a rate of 200,000 Lebanese pounds for every cut tree or shrub in addition to the right of the Minister of Agriculture to issue a decision requiring the caller to reforest the property in the three-year deadline. Otherwise, either the text of the application of Article 97 of the Forest Law in terms of acquisition of this land and auction it to be reforested is applied

or the land is seized for reforestation at the expense of the Ministry and the caller shall be exempt from these two items in the case of force majeure, which is due appreciation to the Minister of Agriculture.

6. It is strictly forbidden to cut old and rare trees that are determined by MOA based on legal provisions in force.

Consulting with the Ministry of Justice[5]

The Ministry of Agriculture has raised many questions regarding the application of the forest Laws and asked the Ministry of Justice to clarify the application of the Law in some cases. Accordingly, several legal counseling have been issued including:

Counseling No. 405/2006 dated July 19, 2006: according to which it is possible to grant a license for thinning dense stone pine forest as long as it leads to preserving the forest wealth and taking care of it.

Counseling No. 813/2004 dated December 6, 2004: It is not possible to cut down resinous trees in order to reclaim the property and plant it with fruit trees.

Counseling 498/1992 dated September 15, 1992: It is not possible to license cutting of resinous trees damaged by climatic factors.

Counselling No. 67/2000 dated February 1, 2000: It is allowed to log dead conifer trees killed due to insects and diseases and transport them outside the forest in order to avoid the spread of insects and diseases to healthy trees. This was based on the objective of Law 85 to preserve forest wealth. There is a need, however, to make sure through technicians that affected trees are completely dry.

Based on these counselling it is clear that the Advisory Board's decisions at the Ministry of Justice are related, on one hand, to the identification of the objective of cutting for preservation of forest wealth, and on the other hand, to the technical opinion (mainly set by MOA). In this context, the goal of a forest management plan that is developed by specialists is very often protecting the forest, and simultaneously ensuring its sustainability and maintenance. Accordingly, the development of a management plan is in line with the Law No. 85 (1991) and the forest law materials issued in 1949. Since the RDNRD is in charge of the protection of forest wealth, it is the only party that can bring, accompany, and monitor the implementation of a forest management plan.

Lebanon's National Strategy for forest fire management (Decision No. 52/2009)[6]

Lebanon's National Strategy for forest fire management (Decision No. 52/2009) addressed various aspects related to forest fuel management. These included:

[5] *Unofficial translation from Arabic*

[6] *Unofficial translation from Arabic*

Item 3 of the Second Component of the Strategy (in Risk modification: fire vulnerability reduction and prevention of harmful fires):

- Develop and explore opportunities such as innovative management systems, and economic incentives to help adopt fire resilient land uses and landscape pattern.
- Modify risk through a number of means such as traditional farming practices with some controlled and enforced livestock grazing in forests, encouragement of sustainable fuel wood collection, incentives for farmers/herders not to burn crop residue and pastures during "fire danger" times, encouragement of Non-Wood Forest Products which can play a role at reducing risk, and incentives for farmers to plough fuel breaks around the perimeter of fields.

Item 5 of the Second Component of the Strategy (in Risk Modification: Fire Vulnerability Reduction and Prevention of Harmful Fires):

Develop preventive silviculture and fuel management aiming at reducing the highly flammable biomass and management of the forests to increase their resistance to fires (or reduce their susceptibility to fires). This includes but is not limited to:

- Grubbing and pruning
- Tree thinning
- Brushwood crushing
- Prescribed burning
- Controlled grazing

Item 5 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation):

- Develop post-fire active restoration/rehabilitation protocols and activities (forest landscape restoration)
- Facilitate natural forest regeneration
- Undertake reforestation activities in areas where regeneration is not possible

Item 6 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation):

- Support ecological restoration actions undertaken by the Department of Forests and Natural Resources at the MOA to recover resilient vegetation types for reducing fire risk
- Assist natural regeneration by protecting the burned areas

Item 7 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation):

- Develop post-fire snags and woody debris management guidelines for the Lebanese forest ecosystems and forest areas
- Modify the existing legislation that prohibits the removal of burned trees accordingly

BKESSINE FOREST

2 Study area and dataset description

Location and extent of the study area

The village of Bkessine is situated in South of Lebanon in the Caza of Jezzine on the western slope of Mount Niha at an average of 786 m above sea level. The central coordinates of Bkessine are 33°34'00.24" N and 35°34'35.38" E. It is approximately 70 km away from the capital Beirut and 23 km away from Saida (Figure 1). Bkessine counted 200 permanent residents (estimation), a number which goes up to 2,000 inhabitants during summer season.

The surface area of Bkessine is about 500 hectares, around 220 hectares of which constitute one of the largest eastern Mediterranean Stone pine (Pinus pinea) forest. The forest is bordered from the North by the town of Bkessine and from the South and East by local water streams. Figure 1 shows the extent of Bkessine cadastral unit and the perimeter of the stone pine forest.

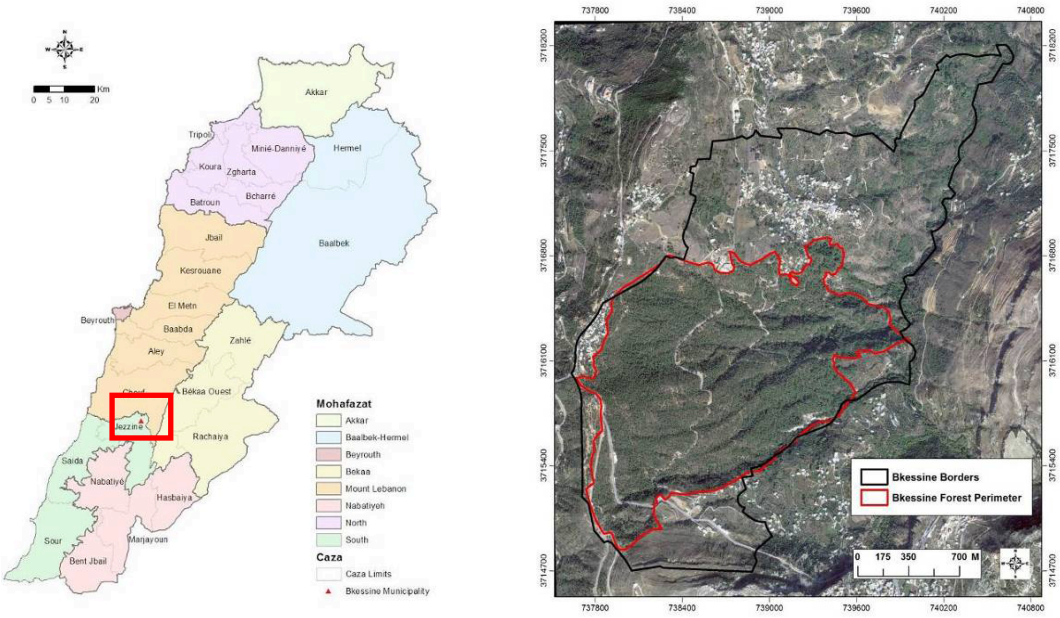


Figure 1. Location of the study area (left), Bkessine cadastral borders and forest perimeter (right)

Biophysical characteristics of the study area

Climate

The study area is typically characterized by a Mediterranean climate, having a humid winter with precipitation mainly occurring between the months of October and March and a semi-arid summer between April and September. The average annual precipitation varies between 900 and 1,200 mm and the mean annual temperature is around 15°C (MOE/UNDP, 2011). Long periods of frost are not frequent; however, snowfall in winter still causes significant damage to pine trees (many windfall and broken branches).

Topography

Bkessine forest lies in the EU-Mediterranean zone between 550 m and 1,100 m of altitude. The forest lies on numerous ditches, ravines and gullies with East/West orientation. The topography shows steeper slopes in the East and South-East, and lower slopes in the West and North-West parts. The slopes are mostly between 15 and 20% whereas some slopes of 20 and 40% are located between the ridges and lines of ridges and trenches (Figure 2).

Figure 2. Sloped terrain of the Bkessine forest

Geology and soils

The forest is carried by the Cretaceous sandstone base. Under the cover of pine, sandstone remained fairly consistent and somewhat eroded. However, soil erosion is more apparent in gullies. Sandy soil is found under the vegetation cover in the forest. It is brown on the surface and more yellow to red with higher depths where iron, sulfur and clay have accumulated (PACA/ONF, 2004). Soil is deep in the trenches and depressions; and superficial on hilltops. Moreover, the sandy structure results in a low capacity for water retention, especially on hilltops and steep slopes making them susceptible to erosion. Soil erosion in parts of the forest northern border) is causing the fall of tall pine trees in the area (Figure 3).

Figure 3. Eroded soil in the northern part of the forest

Hydrology

The topography and the impermeability of the deeper layers in the area allow the appearance of several water springs channeled by 22 water canals supplying mineral water for drinking and agricultural uses (Figure 4).

Figure 4. Water canal in the Bkessine forest

General description of the forest

History

The Bkessine pine forest is mainly a stone pine forest (Pinus pinea) known to be planted in the 1860's. The understory of the forest has been cultivated of wheat and the slopes were managed into terraces of which the remains can still be seen in the forest nowadays.

Cultural heritage

In addition to the natural heritage of the Bkessine forest and the traditional water sources and the old stone bridges from the 19th century located under the forest main road, the forest is surrounded by several monuments of cultural value. The Saint Takla Church was built on the ruins of an old church (1928), Saint Mary Church dating from 1894, the heritage stone houses, and various old olive oil presses and mills Figure 5.

Figure 5. Old house in Bkessine

Woodland types

Bkessine forest is mainly composed of stone pine (Pinus pinea). The current number of stone pine trees (Figure 6) was estimated to be around 100,000 trees, but the current inventory indicated the real number is closer to 55,000, which are found in association with oak maquis (Quercus calliprinos, Q. infectoria, Q. cerris L. var. Pseudocerris). Moreover, some clusters of Calabrian pine (Pinus brutia) trees and prickly Juniper (Juniperus oxycedrus) in the understory can also be found randomly dispersed in the forest. Other native tree species include the Syrian maple (Acer syriacum, common Arabic name: Al kaykab al souri), the yellow hawthorn (Crataegus flavida, common Arabic name: Al zaarour al asfar) and the sycamore (Platanus occidentalis, common Arabic name: Al delb).

Figure 6. Stone pine forest and understory

Forest Products

On one hand, the most important of the non-wood forest products (NWFP) are the pine nuts which result in high economic revenues. Other NWFP include aromatic and medicinal plants such as Myrtus communis, Lavandula sp., thyme (Thymus vulgaris), Gundelia (Gundelia tournefortii, common Arabic name: Aakoub), and the Mediterranean sea holly (Eryngium bourgatii, common Arabic name: Kors Anneh) among others. These products, unlike the pine nuts, are collected by the community for domestic use (e.g. culinary, medicinal…). On the other hand, wood products resulting from pruning activities of pine and oak are not sold but distributed free of charge every year to the community for heating purposes.

Fuel Types and Combustibility

Fuel refers to the flammable material such as tree, shrubs, and grass which allow a fire to occur and spread. The fuel type data for Lebanon were produced within a collaborative work between the Institute of the Environment at the University of Balamand and Lebanon Reforestation Initiative (LRI) in 2013, adopting the Prometheus fuel type classification system[7] which is considered to be better adapted to the Mediterranean ecosystem (Mitri et al. 2015). This classification is principally based on the height and density of fuel, which directly influence fuel combustibility and the intensity and propagation of wildfire (Table 1).

[7] *PROMETHEUS S.V. Project (1999) Management techniques for optimization of suppression and minimization of wildfire effects. System Validation. European Commission - Contract number ENV4-CT98-0716*

The Bkessine forest comprises zones of different densities in vegetation cover (including trees, shrubs, and grass). In some places across the study area, thick forests developed characteristics of multiple layered vegetation formations that support an increased fire spread.

The Firelab[8] web application developed by the BP-IOE-UOB in 2014 shows an accurate distribution of fuel types per village (Mitri et al. 2014). Accordingly, Bkessine as a village, is characterized by ladder-like fuels with large areas (237 ha) of fuel type 6 and 7 which represent tree stands with medium to heavy shrub cover (Figure 7) resulting in high combustibility of the forest. In 2014, a surface fire burned a relatively large extent of understory vegetation in the southern part of the forest.

Table 1. The different types of fuel and their description according to Prometheus classification

Fuel type	% Coverage	Description	Combustibility
1	Ground fuels (cover > 50%)	Grass	High
2	Surface fuels (shrub cover > 60%; tree cover < 50%)	Grassland, shrubland (smaller than 0.3-0.6 m and with a high percentage of grassland), and clear-cuts, where slash was not removed.	Moderate
3	Medium-height shrubs (shrub cover > 60%; tree cover < 50%)	Shrubs between 0.6 and 2.0 m.	High
4	Tall shrubs (shrub cover > 60%; tree cover <50%)	High shrubs (between 2.0 and 4.0 m) and young trees resulting from natural regeneration or forestation.	Very high
5	Tree stands (>4 m) with a clean ground surface (shrub cover < 30%)	The ground fuel was removed either by prescribed burning or by mechanical means. This situation may also occur in closed canopies in which the lack of sunlight inhibits the growth of surface vegetation.	Low
6	Tree stands (>4m) with medium surface fuels (shrub cover > 30%)	The base of the canopies is well above the surface fuel layer (>0.5 m). The fuel consists essentially of small shrubs, grass, litter, and duff.	High
7	Tree stands (> 4m) with heavy surface fuels (shrub cover >30%)	Stands with a very dense surface fuel layer and with a very small vertical gap to the canopy base (<0.5 m).	High

[8] *http://ioe-firelab.balamand.edu.lb/*

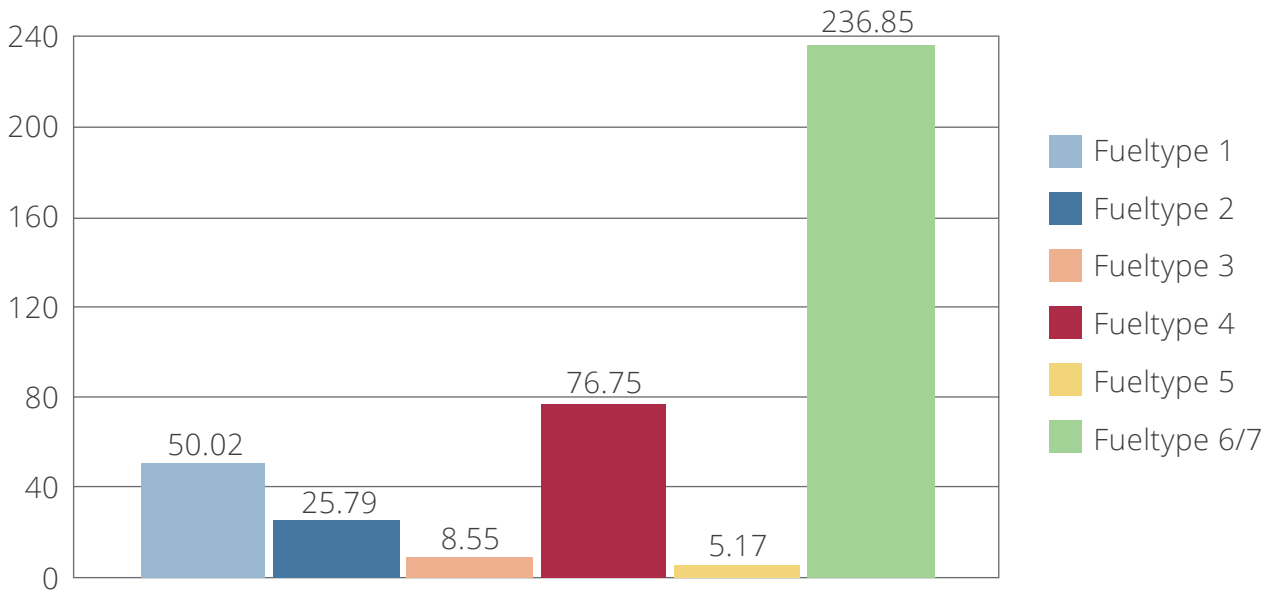


Figure 7. Distribution of fuel type areas in Bkessine (Ha)

Dataset description

- Literature reviews of previous studies and relevant information
- Satellite imagery, GIS data, and topographic maps for the mapping of forest stands, roads, rivers, and management units, among others
- Field visits for field data collection and measurements
- Personal communications and surveys for further data and information extraction

Seven field visits to Bkessine were conducted on the 5th of February 2015; the 1st, 2nd and 3rd of March 2015, the 13th of March 2015, and 14th and 15th of April 2015. The visits consisted of:

1. Compilation of the available documents and previous studies through personal communications with the community and the municipality members
2. Collection of the general forest inventory data and the identification of the management units
3. Measurements of weights of pruning residues

Table 2. Type of data and sources used for data collection

Type of data	Source
National Reports	• National forest Law (1949) and other legal documents • Forêt Communale de Bkessine: Plan de Gestion Durable 2005-2014. (PACA/ONF, 2004) • FireLab Bkessine Village Reports (UOB, 2015) • Lebanon's National Strategy for forest fire management (De cision No. 52/2009) • National forest Resources assessment reports (FAO, 2005, 2010)
Scientific articles and papers	• De-Miguel, S. et al. (2014) • Palahí, M., S. et al. (2008) • Shater, Z., S. et al. (2011) • Hadaet-Obeyed, M. (2014) • Zianis, D., et al. (2011) • Hadaet-Obeyed, M. (2008) • Calama, R., et al. (2008) • Calama, R., et al. (2005) • Calama, R. and Montero, G. (2005) • Calama, R. and Montero, G. (2004) • García-Güemes, C., (1999) • García, C., et al. (2002) • García-Güemes, C., et al. (2001) • Madrigal, G., et al. (2009) • Manso, R., et al. (2014) • Pique-Nicolau, M., et al. (2011)

Type of data	Source
Satellite imagery	• SPOT Imagery (2.5 m) – 2011 • WorldView Imagery - 2014
Maps	• Land Cover Land Use map of Lebanon of 1998 • Digital Elevation Model (DEM) of Lebanon (25 m) • Cadastral units map
Inventory data	Field measurements in plots: • Species composition, cover and density, regeneration, health & general site condition • Tree distribution by diametric classes • Dominant trees diameter, height, age, growth (diameter increments), crown shape and wood condition • Crown biomass fine and coarse fractions
Surveys	Personal communications in Bkessine: • Mr. Habib Fares (President of Bkessine Municipality) • Mr. Maroun Aziz (President of the Committee of Forests and Environment of Bkessine Municipality; president of the Cooperative of Native Tree Producers of Lebanon)

BKESSINE FOREST

3 Forest Inventory

General Forest Inventory

Scope of the inventory

The inventory encompassed the Bkessine forest as delineated in the available cartographic sources provided by the Municipality of Bkessine. The adopted projection coordination system is World Geodetic System 1984 - Zone 36 North (WGS84 36N). The total extent of the study area is 220.53 ha, out of which 210.95 ha are occupied by a forest cover and are the object of this inventory.

Forest stands delimitation and mapping

Stand delimitation is an initial necessary step for forest management. The aim of the forest stand delimitation is the definition of the minimum inventory and management unit areas presenting homogeneous site index and later silvicultural characteristics related to specific goals. The scale in forest stand delimitation maps usually ranges between 1:5,000 and 1:10,000 depending on species commercial value, stand characterization data and spatial data availability, and budget constraints.

Stand delimitation is usually done in three phases:

1. A preliminary stand delimitation draft is digitized in–office, based on available geospatial information (e.g. topography, land-use/ land-cover maps, satellite imagery).
2. The preliminary stand delimitation is used to evaluate the need for different strata, design the sampling scheme, and conduct the field sampling.
3. The assessment of forest inventory data from sample plots measured in the field provides evidence to approve or modify cartographic lines, and accordingly, a final map is produced to serve as basis for planning. The final map is also reviewed and approved by the local forest stewards responsible of the treatments and future forest monitoring, as the delimitation is designed to be as permanent as possible over time.

As Mediterranean forests are multifunctional and support multiple uses, stand delimitation and sampling cannot focus only on accurate timber volume (growing stock) or biomass estimation from a certain number of sample plots. Other goals should also be taken into account when planning (i.e. livestock extensive grazing, honey, nuts/seeds, water harvest). Moreover, reduction of losses from abiotic (i.e. wildfires, wind throw, drought spells) and biotic agents (i.e. game, pests, diseases) also affect management. Therefore, stand delimitation must accommodate current constraints in use or hazards that may influence inventory. For instance, forest recreational areas designated by owners/ management need to be identified as they may require different sampling schemes. Only if all the required information has been correctly structured (by the delimitation) and collected (by sampling), it is possible later to optimize management.

The main criteria and corresponding data used for stand delimitation in Bkessine were related to:

1. topography-site quality that will determine growth/living conditions,
2. recognizable land features to identify stands in the field,
3. previous management delimitations that may have influenced the land cover, or provide data on previous inventories or harvests, and current vegetation cover.

Accordingly, the criteria used for stand delimitation are the following:

a. Site index (SI). This is the stands´ biomass growth potential, it is species-specific and usually measured in classes or ranges that refer to average net annual growth (m3/ha.year) or stand height (dominant height) at a certain age (e.g. Quality A = A m of dominant height at B years).

As this information was not available in cartographic format, we inferred site quality by classifying areas presenting different aspects (i.e. north facing slope vs. south facing slope areas) and slope (indirectly related with soil depth, and, hence, to SI). Topographic differences are relevant in terms of radiation and available water in the Mediterranean basin, where there is at least one discernible deficit period during the year (summer). In places with an important altitudinal gradient, changes in elevation can also be an important factor to be considered. Also, current tree cover may provide insight on site quality. Once the inventory data are processed, dominant height and age can be extrapolated from sample plots to stands allowing estimation of SI or at least a site quality relative classification.

b. Land features, physiographic limits, and infrastructures (LP). Stands need to be easily recognizable in the field and limits should be stable over time to allow for future forest monitoring. For that reason, river channels, topographic break lines (e.g. mountain tops and divides) and roads are usually good permanent border lines to be considered. Although the differences in the vegetation can be also taken into account for that purpose, they should be avoided unless the differences result from land uses in which management is not expected to cause substantial changes that could alter the current cover (e.g. sharp transitions in the vegetation from mature forest to pastures). Cartographic sources of roads, rivers and contour lines at medium-fine scales are usually set as reference. Contour line maps can be easily generated from the Digital Elevation Model (DEM) using GIS tools, as in this case. Hydrography also had to be digitized from available DEM and a WorldView 2014 image.

c. Tree cover (TC). It is the proportion of the surface covered by tree crown projections, usually expressed as a percentage of the total surface (%). It is related with tree density, previous management, soil depth and natural disturbances. It is usually estimated visually with satellite imagery and using GIS tools. In this case, satellite imagery (WorldView and SPOT 2.5 m) was used for cover estimation and stratification of biomass based on Normalized Differenced Vegetation Index (NDVI) values (computed from bands R/NIR).

d. Species composition (SC). We have to account for the dominant species and accompanying or non-target species in the overstory since the silvicultural treatments (i.e. thinning prescriptions and selected stand regeneration method) need to be in agreement with species requirements. This information was mainly acquired in the field.

e. Stand structure (ST). ST refers to the tree distribution per diametric classes, which is known as even-aged when at least 90% of the trees are classified in 2 contiguous diametric classes and uneven-aged when 90% of the trees are classified in more than 2 diametric classes. It is directly related with previous management and/or the occurrence of disturbances causing tree mortality (age). For delimitation purposes it can be evaluated visually from satellite imagery, but once the inventory data are processed, tree cover, species composition, crown stratification and diametric distribution is accurately estimated by the field survey.

f. Minimum stand area. It is the minimum inventory and management reference surface considered in the stand delineation digitization process, usually 10 ha. This is a management-set lower limit based on forest goals, previously available spatial data and human resources for management. However, if forest cover within stands is heterogeneous, smaller units may be digitized for improved yield estimation, but these will not be considered to be permanent units and will homogenize with the application of the silvicultural prescriptions. In Bkessine, the local population acknowledges three general zones for pine cone harvesting and favors certain parts of the forest with local names, so these areas were identified with assistance of the community and members of the municipality, and accordingly, they were digitized. These units sharing past treatments and harvests were considered stands and were used as the building blocks for the 18 management units finally planned (average 6 ha for stands, 12 ha for management units).

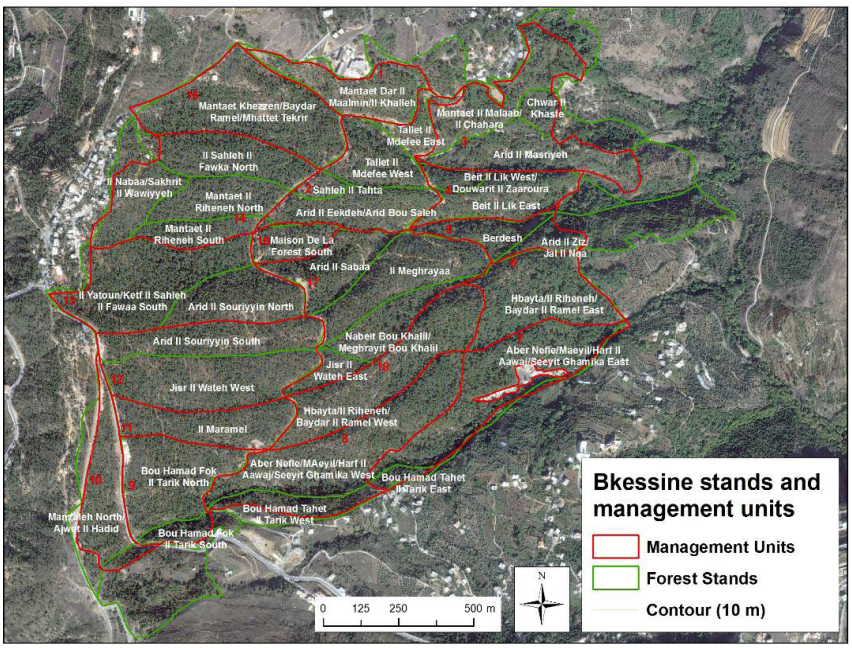
g. Stands of special interest (SS). Areas presenting some singular physical, biological or socioeconomic features (e.g. the presence of endangered species or recreational areas) that forces to consider them independent management units. In these cases the area may be smaller than the established minimum stand area. It is the case of the stand where the Maison de la Forêt is placed, with only 3 ha, but with important constraints in terms of visitor use and recreation management.

A summary of data available for delimitation in Bkessine is presented in Table 3. The base for screen digitizing was the SPOT image with the forest perimeter and locally-recognized stands, roads, ravines, previous management units from the Management Plan 2005-2014 (Plan de Gestion Durable Forest communale de Bkassine – PACA/ONF 2004), and contour lines overlaid, but other sources were continuously checked for accuracy and decision-making when different options were possible. In all cases, agreement with units previously used by the community/ municipality was considered a priority.

Table 3. Summary table containing the main parameters and sources of the parameters considered in stand delimitation.

Parameter (abbreviation)	Theme	Characteristics	Data source
Site index (SI)	Aspect	4 classes (N, E, S and W); 25 m resolution	DEM
	Slope	4 classes (<15, 15-30, 30-60 and >60) 25 m resolution	DEM
	Elevation	25m resolution	DEM
	Satellite imagery	1:5,000	WorldView images (2014)
	Inventory data	Dominant height and age	Pre-inventory data
Land features, physiographic limits and infrastructures (LP)	Rivers	1:5,000	WorldView images (2014)
	Contour map	25 m resolution	DEM
	Road cartography		Roads.shp
	Forest boundaries		Boundaries.shp
Tree cover (TC)	Satellite imagery	1:5,000	WorldView images (2014)
	Satellite imagery	2.5 m resolution	SPOT imagery (2011)
Species composition (SC)	Satellite imagery	1:5,000	WorldView images (2014)
	Satellite imagery	2.5 m resolution	SPOT imagery (2011)
	Inventory data	Species composition (%)	Pre-inventory data
	Land use land-covers	Polygon feature information, dominant species	Land Cover (1998)
Stand structure (ST)	Inventory data	Tree distribution in diametric classes	Pre-inventory data
Stands of special interest (SS)	Recreation areas	1:5,000	WorldView images (2014)

The forest is traditionally managed according to three major zones, since there was not any official management plan adopted until now. However, for practical on-field management, the three principal management zones were sub-divided into several smaller areas which are known to the community by custom; however, they were not accurately spatially defined. The delineation of the specific areas was achieved through personal communications with the municipality members involved in the management activities and through the newly acquired high resolution satellite images in Table 3. The delimitation adopted for this management plan is presented in Figure 8 and in Annex I. The correspondence between Bkessine management units (MU), the units used locally for harvesting pine cones (PCHZones 1, 2, 3) in Figure 9, and the stands (local names) is presented in Table 4.



Produced by the Biodiversity Program, Institute of the Environment, University of Balamand, Lebanon in partnership with University of Lleida, Spain April 2015

Figure 8. Division of the forest in management units and stands.

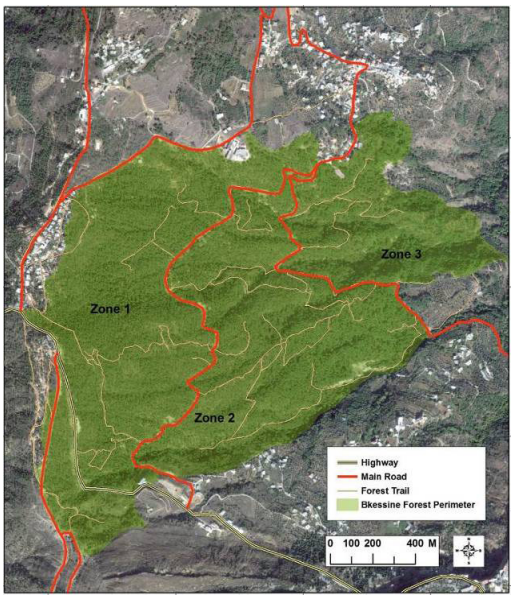


Figure 9. Locally adopted pine cone harvesting zones

Table 4. Composition of management units in Bkessine

MU	PCHZone	Stand (Local name)	MU Area (ha)
1	1	Mantaet Dar Il Maalmin/Il Khalleh (الخلّة/ منطقة دار المعلّمين)	
1	1	Total	6.23
2	2	Arid Il Eekdeh/Arid Bou Saleh (عريض العقدة / عريض بو صالح)	
2	2	Sahlet Il Tahta (سهلة التحتا)	
2	2	Tallet Il Mdefee East (تلّة المدافع شرق)	
2	2	Tallet Il Mdefee West (تلّة المدافع غرب)	
2	2	Total	13.57
3	3	Arid Il Masriyeh (عريض المصريّة)	
3	3	Chwar Il Khasfe (شوار الخسفة)	
3	3	Mantaet Il Malaab/Il Chahara (منطقة الملعب / الشحارة)	
3	3	Total	16.06
4	3	Beit Il Lik East (بيت اللكّ شرق)	
4	3	Beit Il Lik West/Douwarit Il Zaaroura (بيت اللكّ غرب/ دوارة الزعرورة)	
4	3	Total	7.51
5	3	Arid Il Ziz/Jal Il Nea (عريض الزيز / جلّ الناقة)	
5	3	Berdesh (برداش)	
5	3	Total	4.73
6	2	Hbayta/Il Riheneh/Baydar Il Ramel East (حبيطة / الريحاني / بيدر الرمل شرق)	
6	2	Total	9.68

MU	PCHZone	Stand (Local name)	MU Area (ha)
7	2	Aber Nefle/Maeyil/Harf Il Aawaj/Seeyit Il Ghamika East (ساقية الغميقة / قبر نافلة / مأيل / حرف الأعوج شرق)	
7	2	Bou Hamad Tahet Il Tarik East (بو حمد تحت الطريق شرق)	
7	2	Total	12.76
8	2	Aber Nefle/Maeyil/Harf Il Aawaj/Seeyit Il Ghamika West (ساقية الغميقة / قبر نافلة / مأيل / حرف الأعوج غرب)	
8	2	Bou Hamad Tahet Il Tarik West (بو حمد تحت الطريق غرب)	
8	2	Total	16.71
9	1	Bou Hamad Fok Il Tarik North (بو حمد فوق الطريق شمال)	
9	1	Bou Hamad Fok Il Tarik South (بو حمد فوق الطريق جنوب)	
9	1	Total	9.86
10	1	Manzaleh North/Ahwet Il Hadid (المنزلة شمال / قهوة الحديد)	
10	1	Total	6.84
11	1	Il Maramel (المرامل)	
11	1	Total	6.54
12	1	Arid Il Souriyyin South (عريض السوريّين جنوب)	
12	1	Jisr Il Wateh West (جسر الواطي غرب)	
12	1	Total	17.53
13	1	Arid Il Souriyyin North (عريض السوريّين شمال)	
13	1	Il Yatoun/Ketf Il Sahleh Il Fawaa South (الياتون/ كتف السهلة الفوقا جنوب)	
13	1	Total	18.04

MU	PCHZone	Stand (Local name)	MU Area (ha)
14	1	Il Nabaa/Sakhrit Il Wawiyyeh (النبعة / صخرة الواويّة)	
14	1	Il Sahleh Il Fawka North (السهلة الفوقا شمال)	
14	1	Mantaet Il Riheneh North (منطقة الريحاني شمال)	
14	1	Mantaet Il Riheneh South (منطقة الريحاني جنوب)	
14	**1**	**Total**	**18.72**
15	1	Mantaet Khezzen/BaydarRamel/Mhattet Tekrir (منطقة الخزّان / بيدر الرمل/ محطّة التكرير)	
15	**1**	**Total**	**13.17**
16	2	Maison De La Foret South (بيت الغابة جنوب)	9.86
16	**2**	**Total**	**2.72**
17	2	Arid Il Sabaa (عريض السبع)	
17	2	Il Meghrayaa (المِغرّيقة)	
17	2	Jisr Il Wateh East (جسر الواطي شرق)	
17	2	Nabeit Bou Khalil/Megrayit Bou Khalil (نبعة بو خليل / مغريقة بو خليل)	
17	**2**	**Total**	**19.16**
18	2	Hbayta/Il Riheneh/Baydar Il Ramel west (حبيطة / الريحاني / بيدر الرمل غرب)	
18	**2**	**Total**	**11.12**

Field sampling

Sampling intensity (1 plot/5 ha) was estimated from random error formulas with a subsample of a few plots, given the homogeneous conditions in the forest structure, acquired on a first visit to candidate intervention areas. Plots followed a systematic layout over a Universal Transverse Mercator (UTM) grid. Plots layout was circular with fixed radius (between 7-15m, depending on density, as these are easier to layout and correct for slope).

Field survey protocols and measurement sheets for data collection were prepared and used in the field during March-April 2015, including with the usual dendrometric data (i.e. composition, density, diameters-DBH, height/dominant height, age and radial growths (cores), tree configuration, bark thickness, canopy cover, regeneration, health status, spatial distribution, sociological structure, dead and dying trees, etc.), specific blocks for environmental values: ecological and biodiversity information, i.e. understory vegetation, dead wood, erosion, wildlife, unusual sp., or aesthetic value (Figure 10).

Figure 10. Pressler core drilling in process in Bkessine

The protocol and measurement sheets are attached as Annexes II and III. Three full equipment tools were used including 3 measuring tapes 30m long, 3 hypsometers Blume-Leiss (SUUNTO), 3 standard metallic calipers, 3 bark thickness gauges, and 3 Pressler core drillers (HAGLOF). Following the protocol 65 trees were sampled and the cores were taken to the laboratory in Spain (Figure 11) to measure age and current growth (periodic annual increment, PAI, last 10 years). Examination of young trees throughout the forest indicate that 6-7 years must be added to the core ages to obtain actual age, as this appears to be the time period required by trees to reach 1.30 m height. In total, 44 plots were sampled in Bkessine and the complete field forms are attached in Annex IV.

Figure 11. Layout of cores for analysis with magnifying glass

Stand site index

The previous forest management plan (Plan de Gestion Durable Forest communale de Bkassine 2005-2014, PACA/ONF, 2004) proposed three qualities roughly corresponding with position on the slope (the three zones used for harvesting pine cones), but our analysis of the relation age-height in 65 dominant trees sampled suggests that they could be grouped in one for operational purposes. However, for coherence with this previous analysis, we have modeled three functions for dominant height as a function of age (site index modeling), as shown in Figure 12. Data indicates that dominant height at 50 years of age is around 25 m in Bkessine.

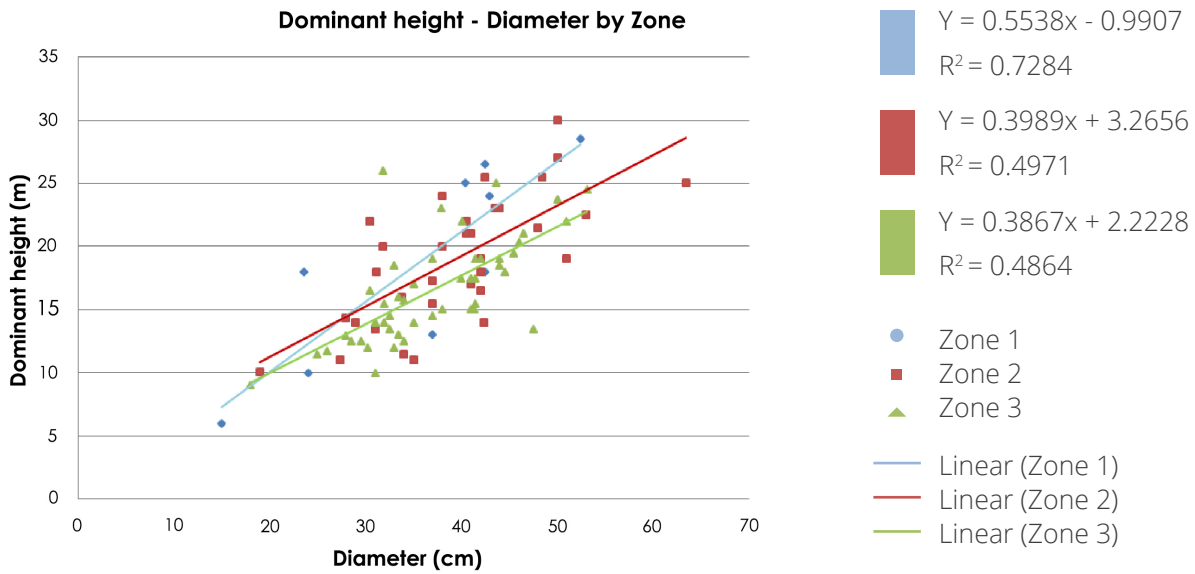


Figure 12. Plot of dominant height and diameter for 65 sampled trees; the three relations diameter-height based on site index (three qualities as in PACA/ONF 2004) were applied to estimate heights in not-sampled trees (for height) in the plots.

Analysis of stand structure

The analysis of data and observations from the field plots confirms that Bkessine is basically an even-aged mature stone pine forest with structure linked to past treatments for the harvesting of the pine cones (tall dominant/co-dominant layer with umbrella shapes). Canopy cover does not always reach 100%. Mixing with Quercus sp. takes place in areas with moisture concentration, close to ravines or lower slopes in the East. Pinus brutia seems to be expanding from the West-Southwestern part of the forest.

The predominant stone pine forest ranges between 32 and >150 years of age, diameters between 22 and 52 cm, and dominant heights 11-28 m (average heights 10-23m). Basal area (BA) for all species averages 5.4-41.5 m2/ha, but 94% belongs to stone pine, and only 6% to other species. General density is 72-495 trees/ha. Diameter growth amounted in the last ten years to 0.66-4.50 cm, causing an increment in volume between 11.5 and 94.4 m3/ha, over the current standing volume (over bark) varying between 100 and 823 m3/ha. Bark depth is estimated at 1.75-3.75 cm.

Regeneration is scarce or absent in all management units. Forest health is judged good in general, regardless the intensive pruning practiced, but should be noted that seasonal/phenological conditions were not optimal for the assessment of forest health. Wood quality is clearly affected by the historical treatment applied that remove branches of large dimensions, leaving a part for climbing purposes. Nodes in the wood diminish timber value. On some plots it was not possible to get a core sample due to bad timber condition, and scars caused by mechanical damage (probably due to past pruning treatments) were often recorded.

Volume estimates and dynamics

Collected data allowed calculating plot-wise models for height in non-measured trees from DBH (Figure 12), used for volume estimation, and diameter increment (periodic annual increment, PAI, last 10 years) for yield estimations. Equations used for volume estimations are summarized in Table 5.

Table 5. Equations used for volume over bark estimation (MOE 2008)

Volume		
Species	**Fraction**	**Equations (dm^3/tree)**
Pinus pinea	Stem over bark	$V=39.96+0.00033*(Dm^2)*(H)$
Pinus brutia	Stem over bark	$V=67.25+0.0002*(Dm^2)*(H)$ *(P. halepensis)*

Where, V is volume over bark - Dm is the midpoint of the corresponding diametric class (10 cm for the range 7.5-12.5 cm; 70 cm for the 67.5-72.5 cm range) - H is the average height of the corresponding diametric class

We checked the possible use of published growth and yield models for Pinus pinea, mainly from Spain (i.e. Calama et al. 2005; Calama et al. 2008; García Güemes et al. 2001; Madrigal et al. 2009; Manso et al. 2014; Pique-Nicolau et al. 2011) and compared them with the model applied by Plan de Gestion Durable Forest communale de Bkassine (2005-2014). Despite the effort to match site conditions in terms of climate, soil, and relations in diameter-height, results are quite divergent among Spanish volume equations and those computed from the previous volume formula (0.5 BA*H; where BA= Basal Area and H is Tree Height). As no equations for volume were available in Pinus brutia, we used Pinus halepensis equations, as these species are very similar in phenotype and ecological role. In order to avoid overestimation of standing volume, and for comparison reasons, we selected the equation with better agreement in terms of site index (National Forest Inventory-Girona), but it is strongly recommended that felled or fallen trees occasionally removed from the forest have their volume estimated to gather information for the future on which procedure is more accurate. Caution on the use and fit of available models precludes insights on dynamics, but the results of the PAI analysis on dominant trees shows extremely low growth rates in the last 10 years throughout the forest, but especially in older trees (1.57 cm diameter increment in trees over 100 years old in ten years) (Figure 13 and Figure 14).

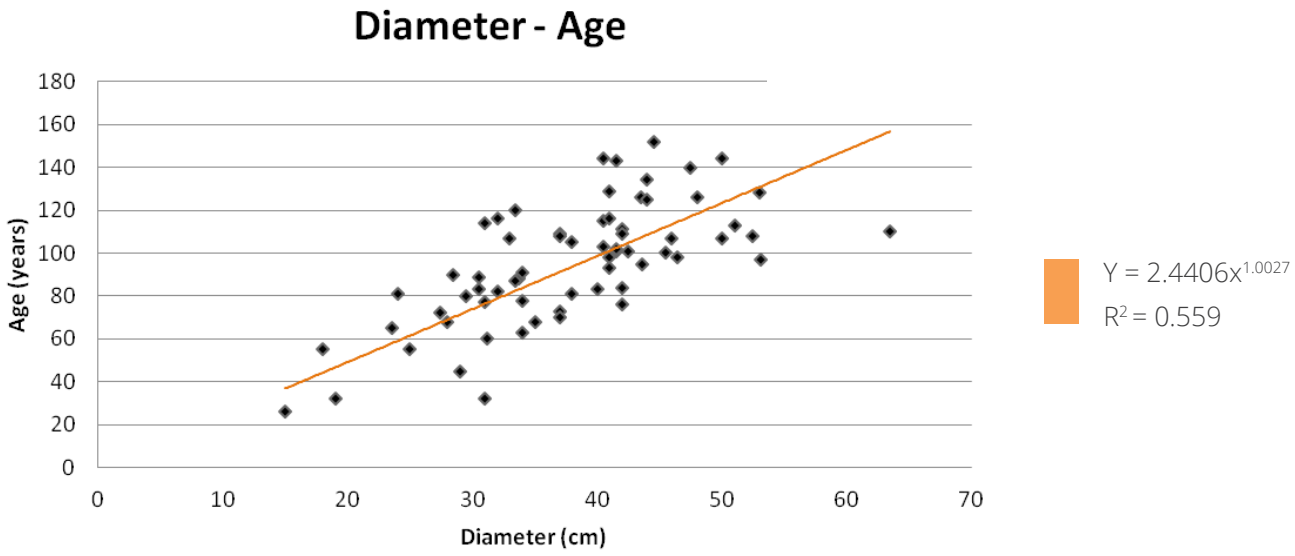


Figure 13. Plot of the relation diameter-age.

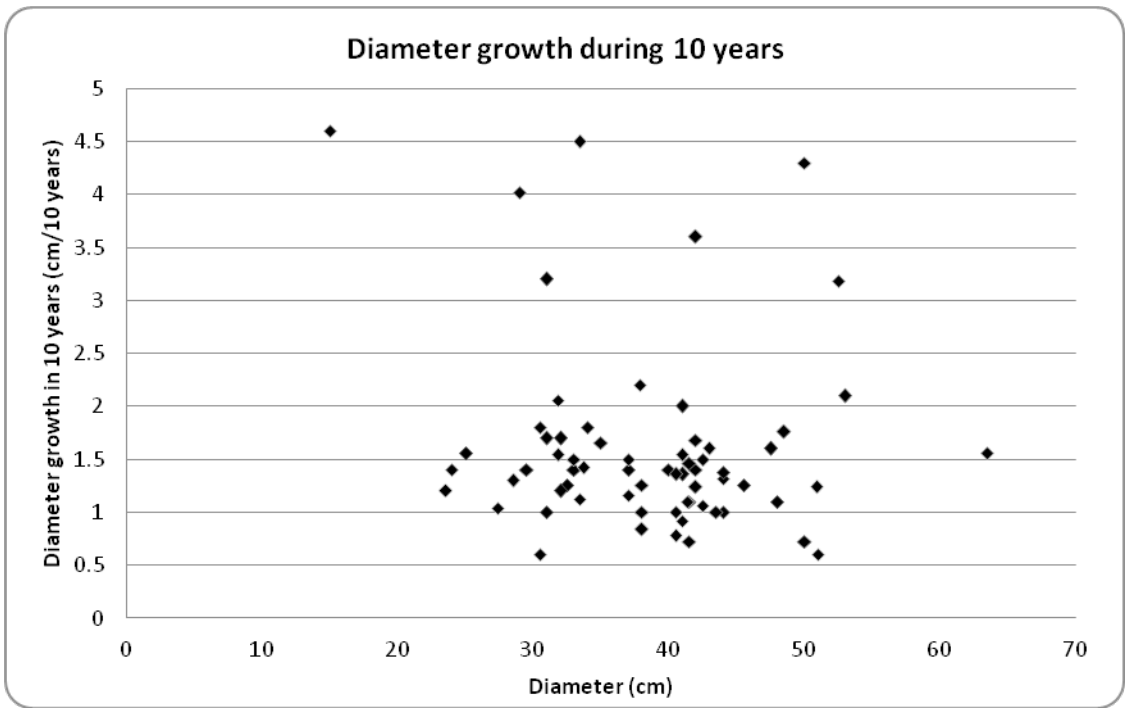


Figure 14. Plot of the relation diameter increment-diameter. No outliers have been removed, but some datum may have been affected by core extraction problems due to timber condition.

Computation of stand volumes and aggregated stand volumes

Taking into account considerations for volume estimations above, a summary of forest characteristics by management unit is presented in Table 6. Complete data for each management unit, detailed by diameter class and species, can be found in Annex V.

Table 6. Relevant variables for the silvicultural characterization of management units (non-forested clearings and roads are excluded)

MU	Area (ha)	P. pinea Diameter (m)	P. pinea Dominant Height (m)	P. pinea Average Height (m)	Density of all tree species (tree/ha)	P. pinea Minimum Age (years)	P. pinea Maximum Age (years)	Basal Area of all species (m^2/ha)	P. pinea Volume (m^3/ha)
1	6.23	0.43	23.25	19.63	249.75	103	109	37.61	349.88
2	13.57	0.31	13.3	14.42	261.86	38	94	20.32	143.1
3	16.06	0.34	18	15.95	182.45	77	87	14.76	124.17
4	7.51	0.29	13.5	13.55	261.27	32	121	16.38	136.26
5	4.73	0.39	27.5	20.46	71.62	114	114	5.43	46.29
6	9.68	0.42	21.88	20.08	318.31	82	150	25.23	205.64
7	12.76	0.44	20.75	19.89	199.73	104	122	28.19	248.16
8	16.71	0.4	19.08	18.64	238.27	51	132	21.93	141.81
9	9.86	0.31	18.25	14.51	311.24	74	106	24.71	147.98
10	6.84	0.3	13.67	13.87	302.98	83	88	22.01	157.24
11	6.54	0.3	13.88	13.43	325.38	61	146	18.8	136.59
12	17.53	0.3	16.25	13.48	283.11	79	158	17.28	91.58
13	18.04	0.36	18.9	18.13	253.41	84	126	18.61	146.03
14	18.72	0.32	16.95	15.01	248.19	86	114	20.87	158.54
15	13.17	0.3	15.25	13.7	251.88	38	104	18.27	141.33
16	2.72	0.39	19	18.58	257.15	60	60	30.13	245.42
17	19.16	0.32	20.38	14.72	296.56	115	150	23.01	167.52
18	11.12	0.4	21.75	19.38	157.32	107	140	18.44	149.06
Averages		0.35	18.42	16.52	248.36	77.11	117.83	21.22	163.14

The process for standing volume calculation was as follows: plots sizes were slope-corrected and their map-projected area was estimated. A plot-wise model for diameter-height was developed and applied to estimate height of not-measured trees from DBH at the plot level. All trees in the plot were used for volume over bark estimation according to the National Forest Inventory-Girona equation (Table 5), applied by diameter class. Volume was referred to ha, and plots in the same management unit were averaged and assigned to the corresponding management unit. Volume increment was computed by increasing diameters accordingly to increments, and applying the same formula. Subtracting the future volume from the current volume provided an estimation of growth/yield for the next ten years. Though it is customary to assume some natural mortality (and volume reduction) will take place (around 1%), our estimations do not include this reduction. We believe that given the age of the forest, mortality in Bkessine will be greater than 1%, and probably increasing exponentially in the future as the forest becomes older, but given the uncertainty associated to this estimation we prefer to advice that mortality is carefully monitored, instead of offering unreliable predictions.

Estimation of tree stem biomass and forest residual biomass

The availability of data organized by species and diametric class for each management unit allows the application of published equations developed by Montero et al. (2005) for biomass fractions (tree stem, coarse and fine fractions) in other species (similar in phenotype and ecological role), but not Pinus pinea.

These equations (Table 7) allow calculation of fractions of biomass in the stem, branches over 7 cm, branches between 2 and 7 cm, and branches under 2cm plus twigs and needles. Modular values of dry biomass by diametric class and fraction are provided, as well as annual increments (whole tree and fractions). These fractions correspond quite closely with the separations performed after pruning in the current practice in Bkessine, so they can be used as an approximation to biomass available for the briquette plant. These estimations are compiled in Annex V by management unit, species and diametric class.

Table 7. Equations used for estimation of dry biomass in fractions for several species (Montero et al. 2005).

Biomass		
Species	**Fraction**	**Equations (kg/tree)**
Pinus brutia (as P. halepensis)	Coarse Biomass (Bc =PT_1+PT_2)	$PT_1=0.0816*(Dm^{2.133})$
	(PT_1 > 7 cm, PT_2 2-7 cm)	$PT_2=(0.0784*(Dm^2))+(-1.9175*Dm)+14.207$
	Fine Biomass (<2 cm)	$B_F=0.0649*(Dm^{2.0349})$
Quercus calliprinos (as Quercus ilex)	Coarse Biomass (BC =PT_1+PT_2)	$PT_1=1.1382*(Dm^{2.0132})$
	(PT_1 > 7 cm, PT_2 2-7 cm)	$PT_2=0.0818*(Dm^{1.9974})$
	Fine Biomass (<2 cm)	$B_F=0.0713*(Dm^{1.969})$
Quercus infectoria (as Quercus pirenaica)	Coarse biomass (BC =PT_1+PT_2)	$PT_1=0.2836*(Dm^2)+(-0.2031*Dm)-5.7606$
	(PT_1 > 7 cm, PT_2 2-7 cm)	$PT_2=0.4506*(Dm^2)+(-11.814*Dm)+64.617$
	Fine Biomass (<2 cm)	$B_F=0.4506*(Dm^2)+(-11.814*Dm)+64.617$

Where, Dm is the midpoint of the corresponding diametric class - B_C = coarse dry biomass; B_F = fine dry biomass - PT = fraction weight (Peso Total in the original)

Estimations are judged valid for selected species but not for Pinus pinea. Stone pine in Bkessine has been subjected to quite intensive traditional pruning in the past that prevents the use of these equations. Their application produced gross over or underestimations depending on diametric class, so we decided to apply simple regression equations developed from field sampling of a few pruned trees in different diametric classes (refer to the Accurate Forest Inventory). Stone pine stem biomass can be estimated from volume over bark, but this potential source is not expected to contribute to the briquette plant, as conifer felling is not allowed for this purpose in Lebanon.

Accuracy assessment of the inventory process and the cartography

Accuracy assessment of the cartography was hindered by the fact that different cartographic sources display different limits for the forest. Our current management area is a bit larger than in the previous Plan de Gestion Durable Forest communale de Bkassine (220.53 vs.204 ha) which calls for a cadastral check.

Errors committed in the estimation of volume at the MU level are well under 15%, which is the upper limit in productive forests in other Mediterranean countries (e.g. in Spain). The statistical error associated to the estimation of volume over bark in m3/ha at the plot and management unit levels is presented in Table 8.

Table 8. Variables for estimation of volume error of the forest

Sampling Error for the forest		
Total Avg. Vol.Pinea	153.52	m^3/ha
Standard deviation	57.17	m^3/ha
Variation coefficient (%)	37.24	%
t student=	2	
Number inventory plots	44	plots
Sampling error (%)	11.23	%

Accurate Forest Inventory

The forest inventory conducted all over the forest was considered sufficiently accurate for management goals in the next ten years of planning, under several scenarios. However, given the stated goal of considering biomass production from the forest to supply a briquette plant with 500 tons capacity in Bkessine, an extra inventory effort was conducted in April 14-18th, 2015, specifically centered in biomass fractions obtainable from the traditional pruning activities that are performed in the forest (Figure 15 and Figure 16). The main source for biomass would be pruning, and possibly, cutting of Pinus brutia trees interspersed in some management units (West-South).

Figure 15. Pruning of sample trees (upper) and gathering of wood for weighting (lower)

Figure 16. Weighting different types of wood collected from pruning

A sample of trees over the range of diameters in the forest was selected. Diameters and heights were measured, and after being pruned under the supervision of the municipal authorities and within the timeframe allowed by the MOA, the corresponding fractions of interest were weighted in the field using a field scale (accuracy 100 gr).

The application of equations available in the literature, mentioned above, produced gross over or underestimations depending on diametric class, so we decided to apply simple regression equations developed from field sampling of a few pruned trees in different diametric classes.

The pruning techniques applied in Spain, location of these bibliographic sources, very much differ from those currently implemented in Bkessine.

As water content was not sampled at the time, an interval is provided instead of a single value, which reflects the possible range of conditions in the season (September 15th and April 15th).

The equations used for ranges of coarse/fine fraction are presented in Table 9.

Table 9. Equations for green biomass estimation in stone pine. The number of samples does not allow calculation of error, but reasonable ranges for values are given based on possible water content for the season.

Biomass		
Species	**Fraction[9]**	**Equations (kg/tree)**
Pinus pinea	Coarse Biomass (>2 cm)	B_c=-6.455+Dm*1.986 /(1.4 or 1.6)
	Fine Biomass (<2 cm)	B_c= -63.895+Dm*8.68 /(1.9 or 2.1)

The coarse fraction usually goes to the community for heating. Diametric class (Dm) values may be input between 20 and 50 cm (diametric classes 20, 25, 30, 35, 40, 45, 50). Extrapolation beyond these values is discouraged. The fine fraction is destined to the briquette plant. Again, diametric class (Dm) values may be input between 20 and 50 cm. Extrapolation beyond these values is discouraged. Diagnostics for these models are provided in Table 10 and Table 11.

Table 10. Diagnostics for Stone pine green biomass models, coarse fractions.

Coarse Fraction	Coefficients	Error	t stat.	Probability	Inf. 95%	Sup. 95%
Intercept	-6.456	16.967	-0.380	0.729	-60.453	47.542
Variable Dm	1.986	0.528	3.763	0.033	0.306	3.665
R^2	0.825					
R^2 adjusted	0.767					
F	14.158					
F critical value	0.032					

[9] *Coarse biomass fraction: biomass in branches > 2cm*

Fine biomass fraction: biomass in branches < 2cm plus twigs and needles

Stem biomass fraction: biomass in the main tree stem

Table 11. Diagnostics for Stone pine green biomass models, fine fraction.

Coarse Fraction	Coefficients	Error	t stat.	Probability	Inf. 95%	Sup. 95%
Intercept	-63.896	112.463	-0.568	0.610	-421.804	294.012
Variable Dm	8.682	3.498	2.482	0.089	-2.449	19.813
R^2	0.673					
R^2 adjusted	0.563					
F	6.161					
F critical value	0.089					

Exploitation of forest residues is done by pruning the traditional way. In addition, we assume that Quercus sp. may also be used, and the forest administration will allow thinning or felling Calabrian pine trees mixed in some stands, as a method to control its expansion and takeover of the stone pine. Resulting usable biomass values computed for each management unit are listed in Table 12, with a detailed estimation of fractions by species and diametric class in Annex V.

The estimation of the usable volumes (m^3) and biomass (ton) in all management units is considered valid for the next ten years (i.e. no difference in obtaining this product on year one, or nine). Stem volume growth due to increment in diameter is estimated in the inventory, but not applied in biomass estimations over the next ten years, as it is low throughout this mature forest.

However, it is strongly advised that a continuous effort for collection of new data is planned in the future whenever pruning is performed, moreover, if new technical specifications are issued (prune 1/3 of crown instead of 2/3). This ongoing collection of data should not be difficult upon the implementation of the briquette plant, which will receive this biomass in a centralized manner over time.

Table 12. Biomass production by management unit in Bkessine.

MU	Pinus pinea (T/ha)				P. brutia (T/ha)		Q. calliprinos (T/ha)		Q. infectoria (T/ha)	
	Coarse_Pruning 40% MC*	Coarse_Pruning 60% MC*	Fine_Pruning 90% MC*	Fine_Pruning 110% MC*	Coarse	Fine	Coarse	Fine	Coarse	Fine
1	11.84	10.36	34.01	30.77						
2	9.00	7.88	24.83	22.46	3.56	1.60			1.10	0.13
3	6.61	5.79	18.40	16.65	0.49	0.25	1.77	0.09	0.68	0.08
4	5.86	5.13	16.58	15.00						
5	1.96	1.72	5.57	5.04			1.00	0.05	0.77	0.09
6	7.46	6.53	21.10	19.09			11.11	0.58	2.04	0.22
7	8.46	7.40	24.16	21.86						
8	7.29	6.38	20.62	18.65	10.33	4.77	4.12	0.21	1.10	0.13
9	9.09	7.95	25.03	22.64	12.77	5.80				
10	11.49	10.05	31.31	28.33						
11	7.78	6.81	21.61	19.55	1.59	0.82			0.87	0.10
12	5.00	4.37	13.97	12.64	12.03	5.58			0.58	0.06
13	7.51	6.57	21.17	19.16	0.94	0.51			0.99	0.11
14	9.14	7.99	25.42	23.00	7.97	3.74			0.30	0.03
15	8.53	7.46	23.53	21.29	1.17	0.54	1.02	0.05	0.17	0.02
16	7.62	6.67	21.32	19.29						
17	9.36	8.19	25.97	23.49	4.13	1.77			2.57	0.30
18	7.18	6.28	20.37	18.43					0.34	0.04

** MC = Moisture Content*

BKESSINE FOREST

4 Bkessine Forest Management Plan

Current management status of the forest

This section describes the current administrative, legal, and technical procedures adopted for the management of the Bkessine communal forest. Initially, it should be noted that the forest was designated as Protected Forest by MOA Decision 3/1 in 8/12/1997 as per the National Forest Law (1949); therefore, its current management is in line with the MOA legal and administrative procedures.

The forest area is a communal land (Machaa) owned by the Municipality of Bkessine. The Municipality is directly involved in the management of the forest through the Committee of Forests and Environment, and participates in the forest conservation and protection activities (Article 54 of the Forest Law).

Although Bkessine counts 8,000 registered individuals, only 200 are permanent residents. This number highly increases during peak times to reach 2,000 inhabitants mostly in summer. In terms of services and employment, the forest provides job opportunities and a set of activities and benefits to Bkessine residents and non-residents.

The main activities currently implemented in the forest are pine cone harvesting, silvicultural treatments (pruning, cleaning and thinning), plantation of seedlings, maintenance of the existing infrastructure (roads, forest trails and water tunnels), and ecotourism among others.

Existing infrastructure

The existing road network in Bkessine forest and its use is described in this section. Roads are divided into the highway, main roads and forest trails (Figure 17). In general, the forest is highly accessible.

The highway provides accessibility to the other surrounding towns and is the main road leading to Saida city and to Chouf and Marjayoun Cazas, therefore, facilitating the transportation of the forest products to larger and farther markets.

The main roads of the forest are used by the Municipality as the basis of subdivision into management units for pine cones harvesting and pruning activities. These roads divide the forest into three primary management zones namely Zone 1, Zone 2, and Zone 3 (Figure 17).

The forest trails inside the three zones are mainly used for access to the forest parts that are far from the main roads. Some are suitable for 4x4 vehicles used during harvesting and pruning; others are only accessible by foot. Forest trails are also an important added value to the forest in terms of ecotourism as they provide hikers with the possibility to access different parts of the forest.

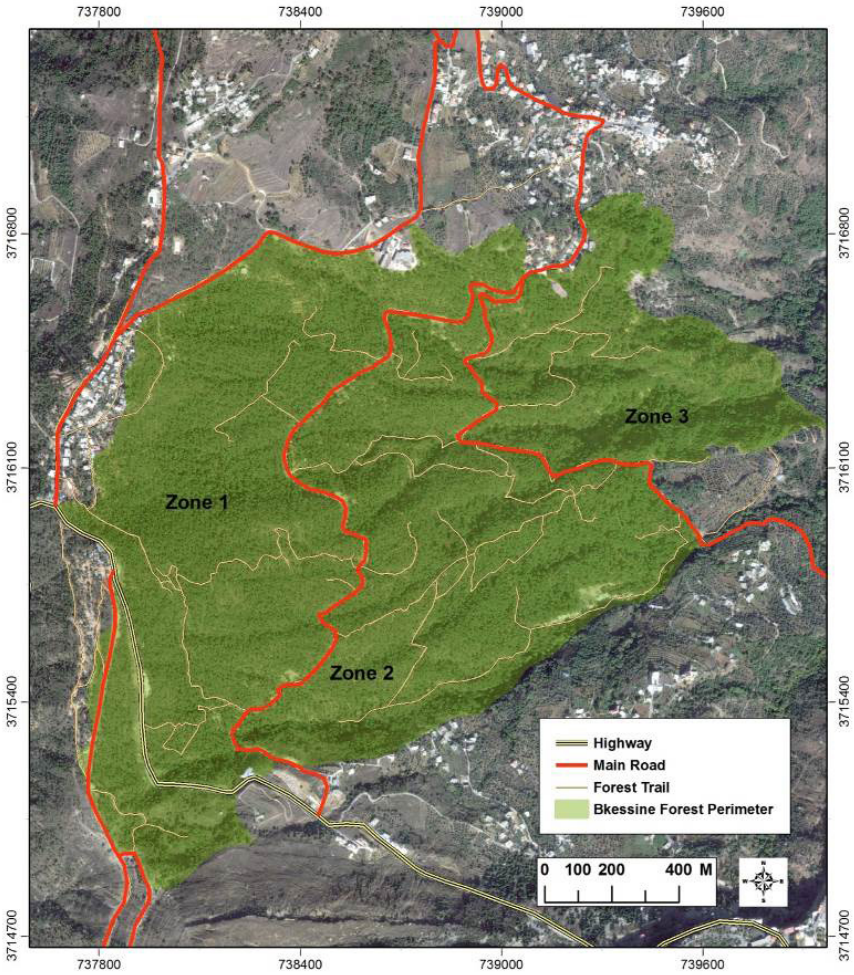


Figure 17. Roads system in Bkessine forest

Additionally, the existing water tunnels in the forest which are fed by the water springs have direct economic benefits which are translated into a reduced water bill for Bkessine residents reaching around 42,000 LBP (approx. 28 USD) per year per household, in comparison to the Lebanese average of 250,000 LBP (approx. 166 USD) per household.

Pine cone harvesting

The administrative procedure for pine cone harvesting is set by the MOA. Accordingly, the Municipality launches a yearly auction to contract pine harvesters for pine cones collection. The works of harvesting (Figure 18) are to be implemented between September 15th and April 15th (Ministerial Decision No 433/1 dated 30/8/2010).

Figure 18. Stone pine harvesting

Estimations of the auction amounts to be adopted for harvesting the forest are made by zone (1, 2 and 3). A field visit is conducted by an officer from the MOA for the valuation of the amount of pine cones available. The amount is kept enclosed in a sealed envelope at the Municipality until it launches the auction. According to the national legislation, one third of the money earned by the Municipality through this process is deposited in the Reforestation Fund (so called Sandouk El Tahrij) of the MOA and under the management of the Ministry of Finance, to ensure the funding of the forest maintenance (e.g. pruning, thinning). Accordingly, the bidding for trees' pruning is set under the mandate of the MOA, the Kaem Makam (Authority of South Lebanon Area), and the Municipality of Bkessine. In 2014 for instance, the pine trees harvesting was contracted for 300 Million LBP (approx. 200,000 USD), of which 200 Million LBP (approx. 133,000 USD) were deposited in the Municipality Fund and 100 Million LBP (approx. 66,600 USD) were used to fund the forest maintenance activities.

According to information reported by Municipality representatives, around 20 families benefit from employments in the production of pine nuts. About 60,000 trees are harvested every year in the forest, giving around 200 tons of pine cones per year and ideally producing an annual average of 8 tons of pine nuts (Figure 19). However, the annual yield might be much less than 8 tons of pine nuts depending on prevailing environmental conditions during the harvesting year. In 2014, the average selling price of one kg of pine nuts was 100,000 LBP (approx. 66 USD).

Figure 19. Pine cones collected from the forest of Bkessine

Silvicultural treatments

As part of the forest maintenance, the pruning and thinning of trees as well as cleaning the understory are financed by the above mentioned Reforestation Fund through a bidding procedure. Similarly, the works of pruning (Figure 20) are to be implemented according to the Ministerial Decision of MOA No. 433/1 dated 30/8/2010 between September 15th and April 15th. However, the silvicultural treatments are implemented in a rotational manner so that the forest needs about 10 years to be entirely pruned.

Figure 20. Pruning of pine trees in Bkessine forest

The main objectives of pruning are to improve the pine nuts production through the opening of the canopy, the removal of damaged branches by weather or insects/diseases and the cleaning of the understory for better access. In addition to the pine nuts product, the forest is a source of fuelwood used by Bkessine residents for heating purposes. Approximately 1,000 tons/year (2 tons/year/family) of wood branches resulting from forest pruning are distributed among residents and used for heating in stoves and chimneys. Every 5 pruned trees provide 1 ton of fuelwood, and small residues for burning. These products are transported in two separate pick-ups (with carrying capacity of 2 tons). The Municipality distributes coupons on families allowing them to collect these residues while accompanied by forest guards.

Moreover, the traditionally adopted pruning technique is generating large amounts of small residues which are not useful as fuelwood (Figure 21). In this case, the residues are burned on site or accumulated under the trees with both practices resulting in a high fire risk. The most recently burned area (March 2014) was investigated during the field visit in February 2015. Such a fire contributed to clearing all surface fuel and scorching the stems of mature pine trees up to a height of 3 meters. Young pine tree were entirely consumed by fires.

Figure 21. Pruning residues in Bkessine forest

In this context, the evaluation of the bioenergy potential of these residues and their use for the production of briquettes would help in mitigating potential fire risk in the forest.

Plantation of seedlings

One of the forest tree nurseries associated to the Cooperative of Native Tree Producers of Lebanon is located in Bkessine. The nursery was established in 2011 with the support of Lebanon Reforestation Initiative (LRI), a USAID funded project implemented through the United States Forest Service (USFS) (Figure 22). The production of stone pine seedlings is done following best practices and improved materials. Pine seeds from the forest are used for germination, resulting in a total of 40,000 pine seedlings that are sold or replanted in Bkessine Forest.

At present, the Municipality uses the seedlings in the reforestation of some low density parts of the forest. Given the very low regeneration rate showed by the General Forest Inventory, a plan for reforestation based on the developed MU should be considered.

Figure 22. Bkessine native tree nursery

Eco-tourism

Eco-tourism is considered as a fundamental source of income for the village of Bkessine where three main eco-projects have been established: La Maison de la Forêt, the guest houses, and Bkessine Picnic Area.

Within the forest, La Maison de la Forêt provides a variety of services: activities, lodging, event organizations and restaurants. In addition to the possibility of lodging in bungalows and tents, visitors (reaching 100 to 200 individuals per weekend in summer) are provided with a list of outdoor activities: climbing and rappelling, treetop adventures, hiking, biking, horse riding, and parlor games. A set of indoor activities (i.e. gymnasium, spa, diet programs) are currently being considered to extend the eco-tourism season to winter period.

Another income generating activity was also developed in Bkessine where at least 4 households are available as guest houses, providing visitors with accommodation and owners with revenues.

The Bkessine Picnic Area also encompasses an attractive set of services for visitors: restaurant serving organic food, market kiosks, area for barbecue, an outdoor space for camping and an indoor space for events.

On-going and forecasted activities

In addition to the above mentioned actions and the project for briquette production from biomass, the Municipality of Bkessine is currently - or aiming at, implementing different projects related to the forest:

- Building and operating the Pine House for processing, packaging, and marketing pine seeds of the forest - expected to open its doors in 2015.
- Producing coal from pruning and thinning hardwood trees such as oak.
- Filling a water reservoir for winter from fountains and rainwater for household usage and irrigation (within the Green Plan).
- Rehabilitating and developing an irrigation system for orchards and agricultural lands (with the Ministry of Energy and Water).

Figure 23. The Pine House of Bkessine (left) and the equipment for processing pine seeds (right)

The Forest Management Plan (2016-2025)

The Municipality of Bkessine and its community are considered as a vital link in ensuring the sustainability of the Bkessine' forest resources. The decisions they make regarding their forests today will impact the quality of the forest for many years.

In this context, a sustainable forestry consists of those management practices that meet present needs without compromising the ability of future generations to meet their own needs. More specifically, sustainable forestry involves reforestation, and the managing, growing, nurturing, and harvesting of wood and non-wood products , and ecosystem benefits such as conserving the soil, air and water quality, sequestering carbon, perpetuating biological diversity, conserving wildlife habitats, improving recreational opportunities, and protecting aesthetics.

The previously described current management procedures were taken into account in this 10-year Forest Management Plan (2016-2025) in order to develop proper and realistic management objectives and to set indicators for assessing their level of achievement.

Management objectives

The main goal of the Forest Management Plan (FMP) is to achieve a healthy and sustainable forest ecosystem which is vital for the well-being of Bkessine community. Therefore, the plan includes economic objectives such as the production of bioenergy and pine nuts in addition to social and environmental objectives, such as ecotourism and forest fire prevention activities.

In this context the FMP of Bkessine forest can be structured into the following three components:

- Production of wood and non-wood products
- Conservation & protection
- Environmental services & social promotion

The management objectives related to these components are developed from the assessment of the forest inventories and current practices in the forest. Table 13 shows the primary objectives with a high priority for achievement within the 10-year management plan, and secondary objectives with lower priority but achievable during the period of the plan.

Table 13. Bkessine forest management objectives and their description

Category	Objectives	Description	Priority
Production of Wood and NWFP	Objective 1. Production of biomass	To provide sustainable and continuous harvest volumes which meet the wood supply requirements for the production of briquettes over the short medium and long term.	Primary
	Objective 2. Production of pine nuts	To provide continuous and high quality yields of pine nuts which support the community and ensure the funding of the Municipality for the maintenance of the forest.	Primary
Conservation and Protection	Objective 3. Fire risk prevention	To develop effective measures intending to reduce fire vulnerability, increase ecological and social resilience to fire, and prevent the occurrence of harmful fires and unsustainable fire regimes.	Primary
	Objective 4. Protection of natural resources	To ensure the conservation and improvement of biodiversity, maintain the productivity of soil, and minimize the impact of forest practices on water quality.	Primary
Environmental Services and Social Promotion	Objective 5. Community engagement	To encourage the effective participation of the local community in the development of the forest management plan.	Secondary
	Objective 6. Maintenance and enhancement of recreation	To provide the public with recreation facilities, services, and information.	Secondary

Forest management units

The GFI resulted in precise stand delimitation and identification of 18 management units (MU) with an average area of 12 ha. The MUs are visually characterized according to density, age, mean diameter, dominant height, volume and biomass (Figures 24, 25, 26, 27, 28, and 29) – (Annex V).

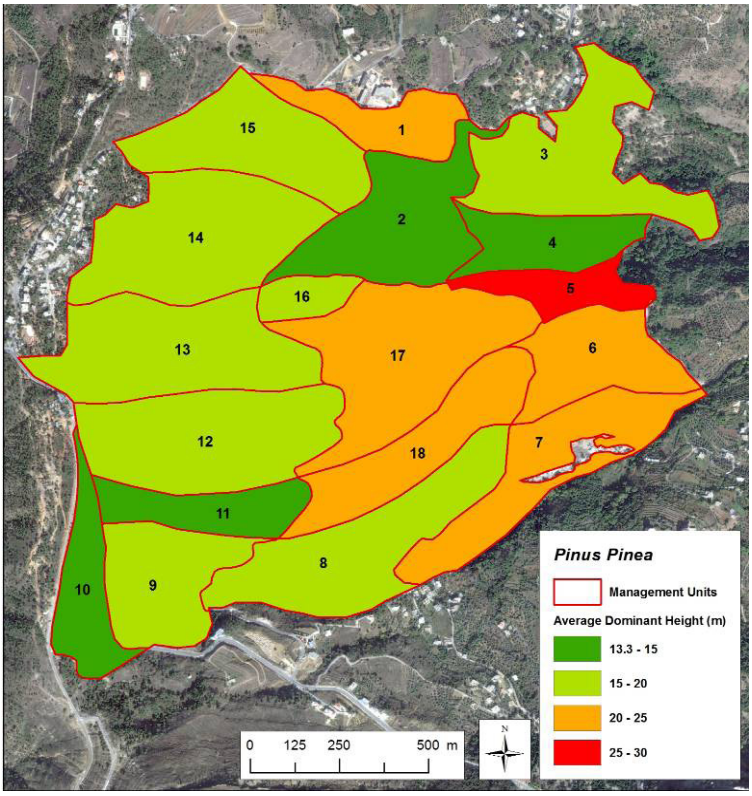


Figure 24. Average dominant height (m)

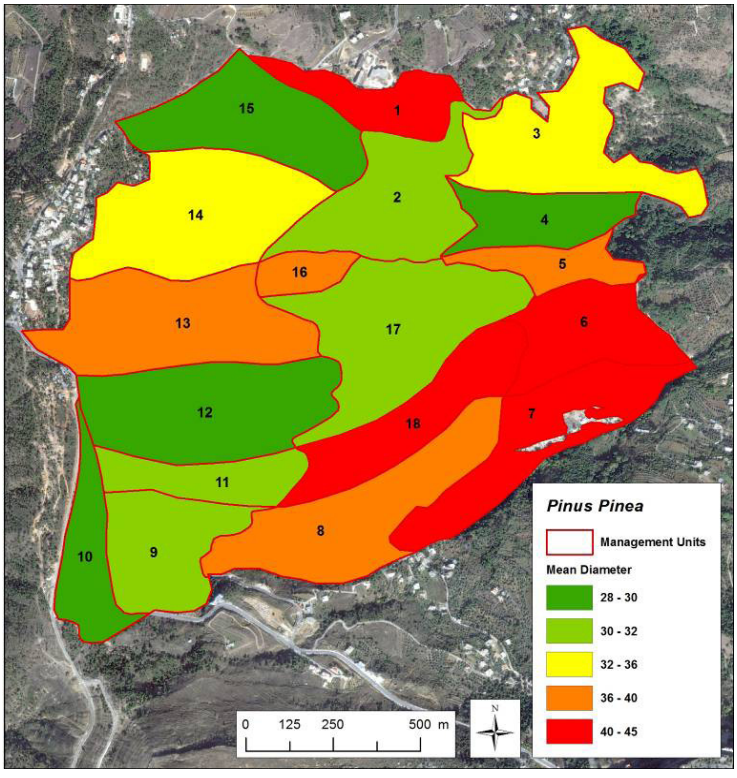


Figure 25. Mean diameter (cm)

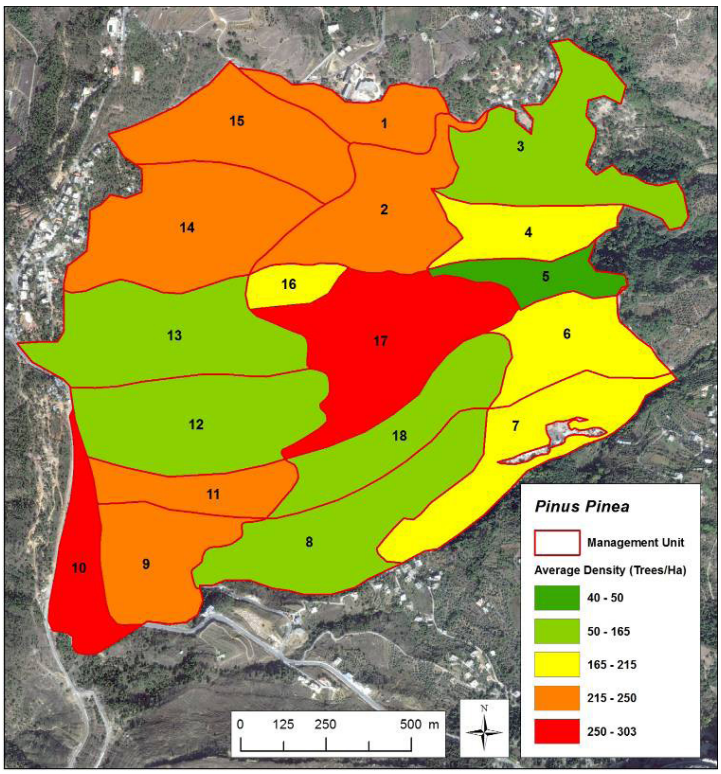


Figure 26. Average density (number of trees per ha)

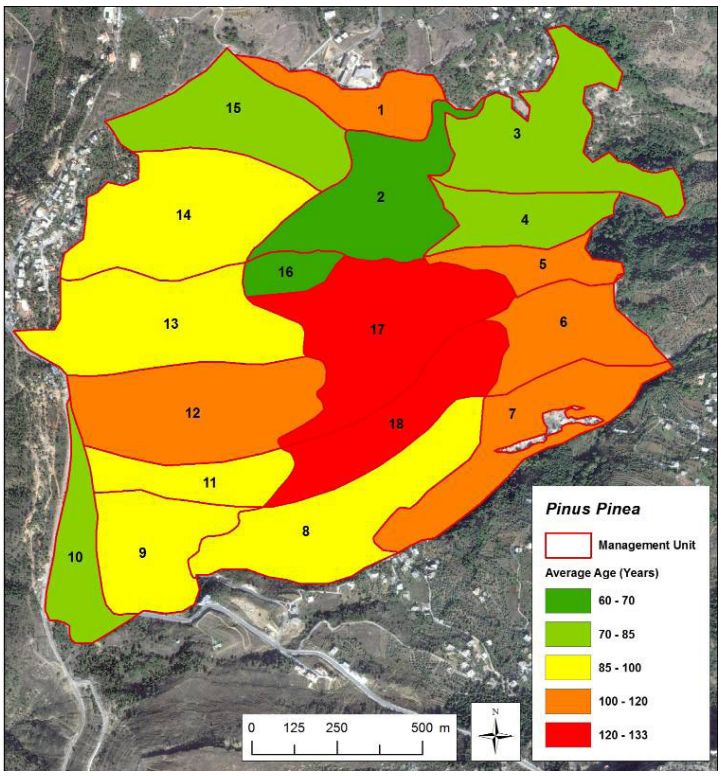


Figure 27. Average age (years)

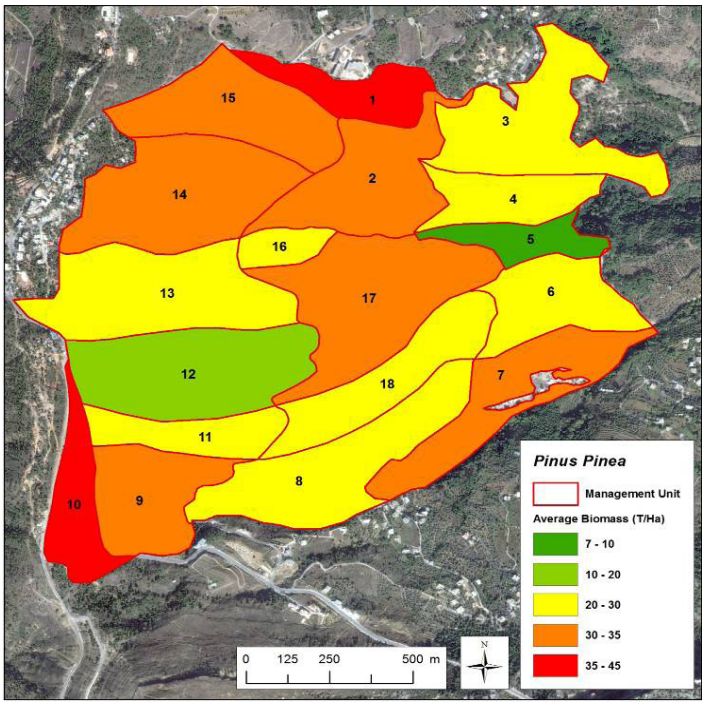


Figure 28. Average biomass (tons per ha)

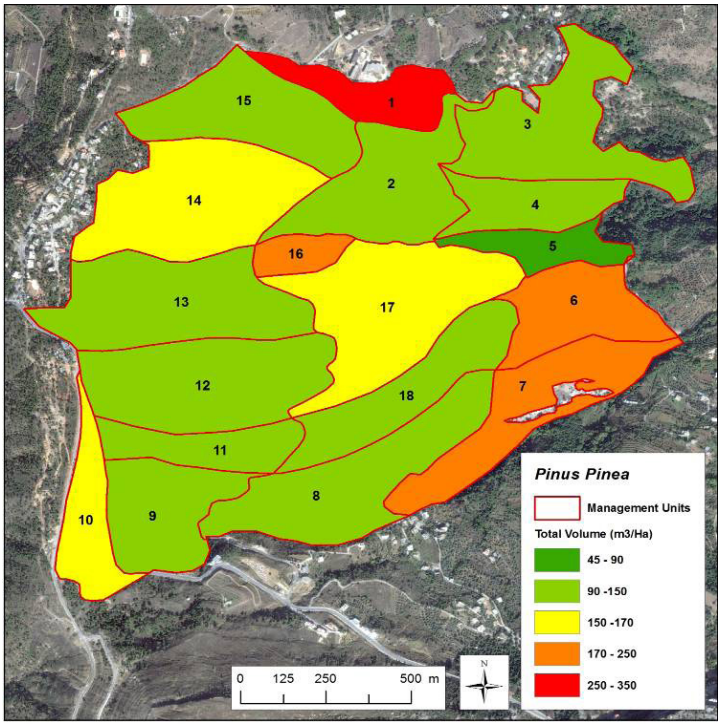


Figure 29. Total volume (m^3 per ha)

Each unit of the MUs is assigned to one or several objectives according to their characteristics in addition to other criteria such as proximity to roads, and ecotourism potential among others. In the purpose of achievement of the objectives, several prescriptions are suggested per MU and each prescription is related to a set of monitoring measures (indicators) and a priority for implementation as per previously presented objectives (Table 14).

Table 14. Bkessine forest management objectives and their description

Objectives	Prescriptions	Indicators	MU
1	Prescriptions and treatments suggested for the achievement of Objective 1 are detailed in the Harvesting Plan in Chapter 5. The plan includes silvicultural treatments such as pruning, and thinning.	Production of fuelwood in tons/year Production of biomass for briquettes in tons/year	Refer to Chapter 5
2	To move the current forest structure into a more balanced age class structure and composition – forest renewal, and to adopt more proper management practices for sustainable pine nuts production: • dentifying and tagging promising trees with good health, free from diseases and insects and having high production (P2.1) • Production of stone pine seedlings in the nursery using seeds collected from the forest (P2.2) • Selecting planting areas and out-planting in a rotational manner after pruning and cleaning the understory. The planted area should not be disturbed for 7 to 10 years (P2.3) • Concentrating planted areas in MUs as it is desirable to create future even-aged areas easier to protect from fires. Concentration of treatments makes them more economically efficient (P2.4) • Monitoring the various agents that can cause damage to the stone pine including perforators like Tomicus sp., Ips sexdentatus, Ips acuminatus, Orthotomicus erosus and Pissodes castaneus Note: Prescription 2.3 and 2.4 are further elaborated in Chapter 5.	Amount of harvested cones (tons/year) Amount of collected white pine seeds (tons/ha) Quality distribution of pine seeds (i.e. 1st choice, 2nd choice, etc.) Density of promising trees Number of produced seedlings in the nursery Plantation scheme (number and distance between seedlings) Number of dead / alive trees Number of trees planted per MU	Refer to Chapter 5

Objectives	Prescriptions	Indicators	MU
3	Prescriptions shall coincide with those of objective 1. Wildfire risk assessment: a. Identifying fuel types, combustibility, topography, infrastructure and land uses (residential areas, industrial developments, recreational areas, public spaces, and dumpsites among others) within the forest (P3.1) • Producing detailed fire hazard map of the forest (P3.2) • Producing detailed fire vulnerability map of the forest (P3.3) • Producing detailed fire risk map of the forest (P3.4) Silvicultural treatments for forest fire prevention: • Creating firebreaks: Cleaning the forest floor up to fifteen meters away from the sides of the roads and in the forest-agriculture interface (P3.5) • Creating fuel breaks: Removing weeds and shrubs along forest trails (P3.6) • Pruning and thinning: removing all the dead twigs from the tree and shrubs, and the green ones only in the first third of the tree's height in order to avoid surface and ladder fuels accumulation. Reducing the tree density to avoid crown fires (P3.7)	Map of fire hazard Map of fire vulnerability Map of fire risk (these maps were produced within the Lebanon's Reforestation Project's Initiative in 2015 to manage wildfire risk in Bkessine) Total cleaned area for establishing a fire break Total treated area for establishing a fuel break Production of fuelwood form pruning and thinning in tons/year	All MUs
4	To ensure the conservation and improvement of biodiversity, maintain the productivity of soil, and minimize the impact of forest practices on water quality (P4.1)	Provisions of a variety of forest cover and habitat (i.e. different aged forest stands, a variety of species, and forest openings) Measures taken to stabilize soil in eroded sandy areas	All MUs

Objectives	Prescriptions	Indicators	MU
5	Training of the community involved in silvicultural = activities for the implementation of the harvest plan (P5.1) Developing nature and forest management interpretation programmes (P5.2) Raising awareness campaigns for the local community about the benefits of sustainable forest management practices (P5.3)	Number of people trained in silvicultural activities Adopted nature and forest management interpretation programmes Number and dates of awareness activities and events held and number of awareness material produced and disseminated	All MUs
6	Maintaining the forest trails (P6.1) Maintaining camping areas (P6.2) Locating watch sites (P6.3) Disposing efficient garbage disposal system (P6.4) Protecting and promoting monumental trees (P6.5) (e.g. protecting the trees nicknamed 'King' and 'Queen' from leaning and eventually falling and promote their existence to visitors) Protecting sites of aesthetic values (P6.6) Promoting responsible ecotourism activities in Bkessine (P6.7)	Distance of trails maintained Number of annual users of campers Number of watch sites established Number of placed garbage bins/containers Number of protected and promoted monumental trees Protected streams and other visually appealing features	All MUs

Plan overview

A detailed work plan for managing the biomass in MUs is presented in Chapter 5. As previously stated, the general objective of this work is to evaluate the capacity of the municipal forest of Bkessine for providing biomass for heating purposes, in a sustainable, well planned, and prioritized manner and inclusive of the main traditional and new uses of the forest. Accordingly, the work plan comprises descriptions and characterizations of prescriptions and activities mainly related to Objectives 1 and 2.

The main stakeholders and beneficiaries from the management plan are: MOA, Union of Municipalities in the Caza of Jezzine, Municipality of Bkessine, harvesting (pine cones) contractors, pruning and thinning contractors, the local community of Bkessine, Cooperative of Native Tree Producers, Maison de la Forêt, Directorate of Civil Defense (Center of Bkessine), and visitors. Their roles and responsibilities in the implementation of the management objectives are detailed in Table 15.

Table 15. Description of stakeholders and beneficiaries of the management plan, their roles and responsibilities

Stakeholders/ beneficiaries	Management objectives	Roles and responsibilities
MOA	1, 2, 3, 4	Provide necessary permits for silvicultural treatments such as pruning and thinning Provide effective monitoring and control of silvicultural treatments Provide technical support to the Municipality for the implementation of its plans for regeneration, plantation, and silvicultural treatments Ensure the proper implementation and enforcement of forest laws and regulations Provide flexible framework for the adoption of fire resilient forest cover
Union of Municipalities in the Caza of Jezzine	3, 5, 6	Contribute to forest fire risk management through the involvement of neighboring municipalities Mobilize necessary resources for forest fire prevention and risk management Contribute to raising awareness campaigns for the local community groups about the benefits of sustainable forest management practices Monitor the arrival and outbreak of certain pest and diseases that can affect trees

Stakeholders/ beneficiaries	Management objectives	Roles and responsibilities
Municipality of Bkessine	1, 2, 3, 4, 5, 6	Manage the implementation of the forest management plan Manage the implementation of the forest harvest plan Ensure sufficient financial resources for the implementation of the forest management and harvesting plans Launch the tenders for pine cones harvesting and for pruning and thinning (if needed) Acquire all necessary permits and licenses for pruning and thinning activities in the forest Provide and operate necessary infrastructure/equipment for processing biomass residues Ensure adequacy and maintenance of forest infrastructures and installations Monitor the arrival and outbreak of certain pest and diseases that can affect trees Build the capacity of users about good practices on silvicultural treatment and fire management (in case they are allowed) based on the existing regulations. Develop agreements with companies and administrations responsible of forest infrastructures for conducting the necessary investments and periodic works for their maintenance Monitor the proper use of recreational facilities Develop awareness campaigns about the fundamental role that the rural population plays in protecting the forest preventing dangerous fires Raise awareness to general public by posters and signposts which warn the public about the danger of forest fires which are placed at conspicuous places of roads, picnic and camping sites and villages
Harvesting (pine cones) contractors	2	Undertake proper pine cones harvesting Properly process collected pine seeds Contribute to Identifying and tagging promising trees with good health, free from diseases and insects and having high production Contribute to the production of stone pine seedlings in the nursery using seeds collected from the forest Make sure not disturbing planted areas for 7 to 10 years after plantation

Stakeholders/ beneficiaries	Management objectives	Roles and responsibilities
Pruning and thinning contractors	1, 3	Familiarize themselves with the harvesting plan Ensure they are trained to properly implement activities suggested in the harvesting plan Undertake proper pruning and thinning techniques Ensure proper handling and disposal of pruning and thinning products
The local community of Bkessine	1, 2, 3, 4, 5, 6	Involve aware individuals from the community to whom awareness raising and surveillance campaigns are addressed, in the awareness/education/surveillance actions.
Cooperative of Native Tree Producers	2	Propagate seedlings in local nursery and originating from local seeds Provide high quality seedlings (free from diseases and damages) for reforestation Provide seedlings certificate of origin Monitor the arrival and outbreak of certain pest and diseases that can affect trees
Maison de la Forêt and the camping and picnic projects	6	Promote responsible ecotourism activities in Bkessine
Directorate of Civil Defense (Center of Bkessine)	3	Mobilize means of fire suppression Train individuals from the local community on forest firefighting
Visitors	3, 6	Avoid the use of any source of fire within the forested area Undertake responsible recreational activities within the forested area

Plan overview

Financial and technical resources for implementing the prescriptions of Objectives 1 and 2 (i.e. in relation to pruning, thinning, and planting) are presented in the Forest Harvest Plan.

Constraints and obligations

The current legal framework in Lebanon prohibits trees cutting for promoting the growth of a young forest. This is considered as the main constraint to the forest rejuvenation. The rejuvenation of the stone pine forest in Bkessine is much needed.

Given the traditional use of the forest for pine cone production, no trees would be removed anyways from the forest as long as they are good producers of seeds. The consequence of not applying 'regeneration' cutting is, unavoidably, that the forest will be affected in the future by gradually increasing falls of trees that will eventually and collapse to the ground, probably after certain weather events. This would also affect safety of the local population, forest workers and visitors.

Regeneration in Bkessine is not linked to the canopy openness. Seed predation rates are high, and cones are collected every year, so the only choice in this case is artificial regeneration/planting. The removal of the over mature canopy will be guided by population safety, production criteria and technical evaluation of potential damage to the new forest growing underneath.

Also, the community is traditionally used to forest management practices which must be taken into consideration, and if changed, changes in management practices must be done gradually and be properly explained.

The trees in the forest have been subjected to quite extreme pruning treatments that remove about 2/3 of the crown. While this causes potentially health problems to the trees, and probably reduces pine cone production, it is argued by the community that this treatment reduces damage by snow and storms. True or not, there is little benefit in drastically changing the treatment for mature trees. Efforts should focus in creating conditions for the establishment of younger generations with different technical specifications for pruning: reducing tree height, widening the crown, cutting non-photosynthetic branches, and improving the wood quality in the lower part of the trunk for future use with more added values.

The proposed/current Management Plan fully supports conclusions of the previous 2005-2014 Plan de Gestion Durable Forest communale de Bkassine (PACA/ONF, 2004), especially in what is specified on the need for rejuvenation of the forest, the protection of floristic diversity, the need of better conditions (habitats) for wildlife, reduction of fire risk, and improvement of socioeconomic outputs. However, some modifications silvicultural treatments are suggested here regarding the technical specifications by which these can be achieved.

BKESSINE FOREST

5 Forest Harvest Plan

Scope of the Harvest Plan

This Forest Harvest Plan aims at supporting an improved decision-making with regard to pruning, thinning, and planting the previously determined MUs.

Most forest management plans are designed for 10 years, and estimated increments are usually valid for 10 years. Accordingly, the planning period adopted here is also for 10 years.

Management unit and harvesting blocks

As the previously presented forest inventory allowed the determination of MUs based on the traditional local areas that are recognized by the community, these same MUs were adopted here as harvesting blocks.

However, the forest stands subdivisions that are usually recognized by the community within the MUs were preserved as prescription areas for operational purposes. This would help in locating treatments locally and in facilitating on following up on the planning.

In general, constraints for operations in the MUs are scarce. The whole forest is quite accessible, the topography is favorable, and the forest cover is relatively homogeneous. Also, no major river crossings or other obstacles should be overcome when implementing the forest operations.

Areas in immediate proximity to the abundant ravines in the forest (10 m buffer), especially in MUs located in the Eastern lower part of the forest should avoid machinery operations or damage to vegetation (i.e. Arbutus and Quercus sp.) for reasons related to watershed protection and biodiversity conservation. Natural features such as rocks formations in MU-5, MU-17 or MU-18, or cultural features such as old terraces in MU-11, MU- 14 or MU- 18 should be always respected when applying prescriptions.

Determining potential locations for the harvesting process might be necessary in the future if ‘regeneration’ cuttings (timber production) are planned for, but legal constraints currently prevent this scenario. Given the fact that mainly branches (or small Pinus brutia trees) are to be processed, the ideal location for processing would be at the stocking yard of the briquette plant, which is planned to be installed (based on personal communication with the Municipality) at the site of ‘Dar El Maalmin’ as shown in Figure 30.

Whole branches should be loaded and taken from the forest to the yard to be separated there on site for fuelwood (coarse) or biomass production (fine residues). This procedure would diminish costs, improve safety for forest workers, and help in the collection of the fuelwood (coarse fraction) by the village from a centralized location, where the fine fraction is left for biomass. Needles dropping on-site are good for soil fertility.

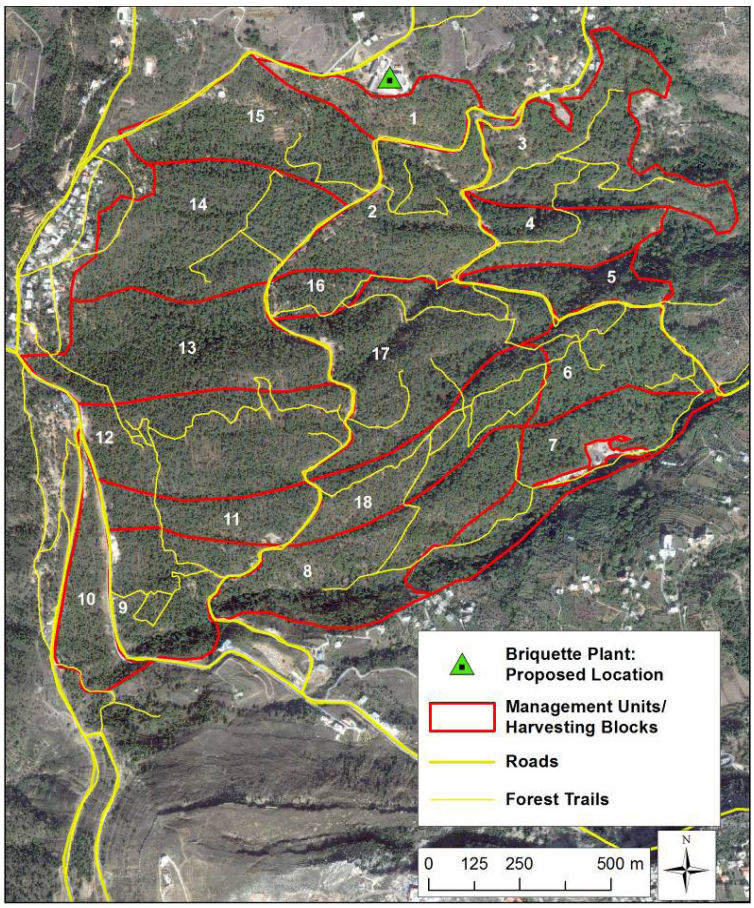


Figure 30. Map showing the suggested location of the briquette production plant

Silvicultural system to be applied by stand type

The silvicultural system proposed may be applied to all stands in the forest, as the structure is a quite homogeneous mature stone pine forest. The structure of MUs is basically even-aged (Figure 31).

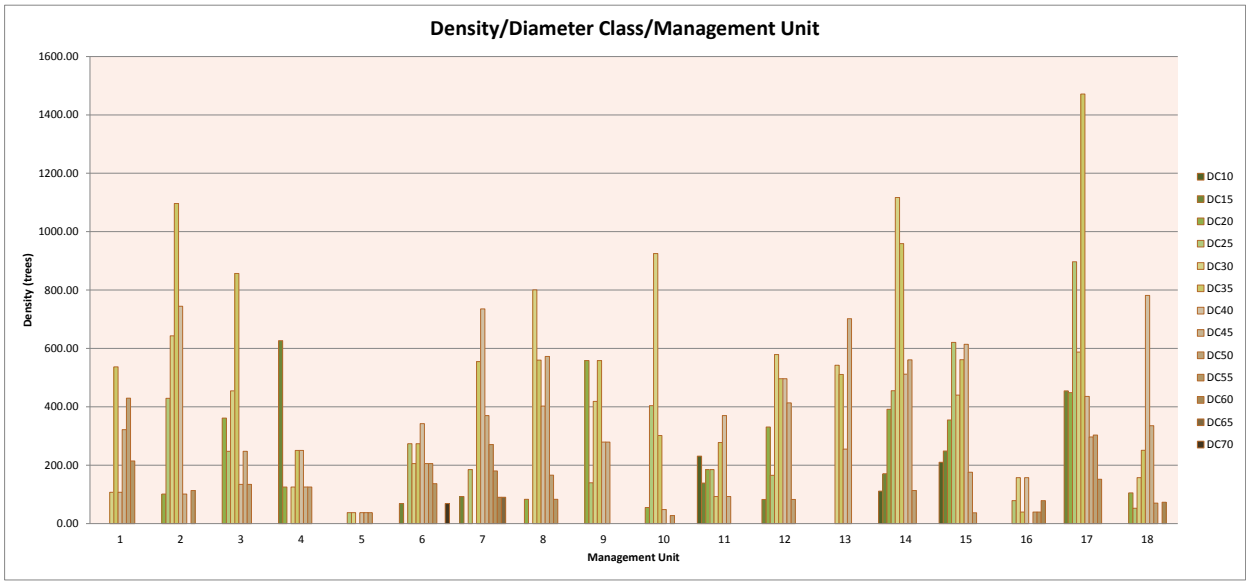


Figure 31. Even-aged diametric distribution by management unit

The previous 2005-2014 Plan de Gestion Durable Forest communale de Bkassine (PACA/ONF, 2004) established a model based on a future uneven-aged structure to be achieved by regeneration openings for sizes varying between large gaps (a few areas) and a few hectares (parquet). The Plan admitted an even-aged structure in Bkessine that would make difficult to reach quickly the aimed uneven age and spatial heterogeneity, but established this structure as desirable for the long-term, for pine cone production and recreational reasons. However, the Plan did not include preferred locations for the planting or a specific system to control the regeneration surfaces. This might complicate the management of the forest by the community and it also requires expertise that may not be available. It is essential to note that monitoring the new young forest should be feasible and easy, and the concentration of tasks in MUs facilitates efficient performance of all types of silvicultural treatments.

Spatiotemporal concentration of treatments may lead to maintaining even-aged structures for a period of time. This might be found convenient to wildfire risk considerations (i.e. safer structure), recreational considerations (better visual penetrability with big tree appearance), and socio-cultural considerations (i.e. the community is used to a regular mature forest). The tendency not to cut a tree as long as it is producing seeds will eventually and naturally lead to an uneven distribution of ages in the forest either in gaps or parquets, as it has been observed to happen in other Mediterranean environments (Spain, for instance).

The forest rotation was theoretically established at 100 years in the 2005-2014 Plan de Gestion Durable Forest communale de Bkassine (PACA/ONF, 2004), but the practical recommendation was to plant 3 ha/year, which really corresponded to a rotation of 68 years (204 ha/68 years). Currently, we do not propose a rotation value as felling in the future will be controlled by biological criteria (life span for the production of seeds and health factors), pine cones remain the primary product of the forest, and the legal framework does not allow for cutting of the pine trees. We agree though with the necessity to expand artificial regeneration in the forest, as we have observed relatively low survival

rates in some plots (40-50%). Accordingly, the plan is to plant all management units identified as requiring urgent planting (i.e. areas with recent fires, low tree density areas, and over-mature forest areas). The recommended planting frame is 4x4 m (625 trees/ha), in a compromise to reduce future tending efforts.

The general prescription for the forest in the next ten years, then, is formulated around regeneration and tending of seedlings, pruning, thinning (high relative density areas in relation to their age) and goal-specific treatments in particular MUs due to recreational significance (i.e. Maison de la Foret, MU 16).

No 'regeneration' cuttings are planned for, but in case the legal constraints are changed or new situations arise, harvest volume estimations are provided for each MU in the Annexes corresponding to the Forest Inventory (Annex V per ha, Annex VI per total values). In this case, age would be the leading criteria for felling.

Biomass products for the briquette plant are estimated from stone pine pruning conducted traditionally for the next ten years, pruning of Quercus sp., in addition to thinning Pinus brutia trees, a competitor species that will eventually replace Pinus pinea if left uncontrolled. Pruning residues will be reduced in the future if recommendations for stone pine younger trees are followed (roughly 1/3 instead of 2/3 crown are removed), which calls for ongoing measurements and record keeping. However, this reduction could be compensated by increased thinning and a certain increase in pine cone production.

Since the forest is stated to be 15 years late in pruning requirements, and rotation for this treatment is estimated optimal every 7 to 10 years, the prescription for this treatment is designed to match temporally the planting. Planting following pruning benefits from the clearing in the understory, and protect the new plants from mechanical damage for a period of 7 to 10 years, though not from the effects of harvesting cones annually. A rotation temporal span of 10 years is recommended, however, and planned under the assumption that budget shortages precluding so far the execution of the works would probably continue to occur. It is worth nothing that selecting a 10-year span for pruning rotation is convenient also for coinciding with the general planning for the forest. Ideally, if such recommendations were followed, pruning can be organized up the end of the ten-year Plan (2025).

This rotation is also beneficial to Quercus sp., but in this case, it is recommended to develop future structure of coppice with standards by selecting and preserving the best shoot in any individual. A more diversified structure for this species and regeneration not restricted to vegetative reproduction is recommended for sustaining of a more diverse forest on the long run.

Anticipation of the future is impossible, but caution should be exerted and monitoring should be considered a must in this regard. In this context, the arrival of introduced pests such as Leptoglossus sp. (already found in Turkey) would be a dramatic setback for the forest ecological and socioeconomic system.

Traditional agents of damage to stone pine include perforators like Tomicus sp., Ips sexdentatus, Ips acuminatus, Orthotomicus erosus and Pissodes castaneus. Advanced adaptations of these

species make them to be found in different parts of the trees. Signs of these insects were found in the survey (i.e. plot 12, Figure 32) but there was no indication of extensive damage or mortality in Bkessine due to perforators. The defoliator Thaumetopoea pityocampa with white nests in the crown, quite easy to discern and treat, was not apparently present. No mention was made by the community about damage to pine cones that may have been caused by Pissodes validirostris or Dioryctria mendacella. Presence of diseases like Lophodermium pinastri in the leaves or Fomes sp. in trunks was also not evident.

The arrival of an invasive species, the western conifer seed bug (Leptoglossus occidentalis Heidemann 1910) would be an important threat to the forest of Bkessine, so attention should be paid to any sign of its presence. Leptoglossus occidentalis was introduced in Italy in 1999, from North America, through wood trade (Lis et al. 2008). It appeared in Spain in 2003, where it is causing many problems, it has expanded to most countries in Europe and it has already been cited in Turkey in 2009. It feeds on the sap of developing cones, and, based on temperature, could reach two to three generations in a year in Bkessine, which may destroy seed production. It has been treated with pesticides in pistachio trees, but all are highly toxic to fish and aquatic organisms.

Figure 32. Signs of insects on the bark of a pine tree in plot 12

Silvicultural prescriptions by management unit

Prescriptions (improvement or regeneration) and treatments (pruning, thinning, and planting) are prioritized and summarized in Annex VII, including the relevant variables for decision-making that characterize each MU, and the biomass to be processed every year.

The list of biomass prescriptions and treatments (organized temporally) are given in Table 16.

Table 16. Biomass prescriptions and treatments in Bkessine 2016-2025

MU	Zone	Area MU*	HB name	Area HB*	Prescription	PR priority	Treatment	PL Year	PR Year
1	3	6.23	Mantaet Dar Il Maalmin/Il Khalleh	6.23	IMPROVE	PRUNE-1	-	-	2016
2	2	13.57	Tallet Il Mdefee West	4.76	IMPROVE	PRUNE-1	-	-	2017
			Arid Il Eekdeh/Arid Bou Saleh	5.94	IMPROVE	PRUNE-1	-	-	2020
			Tallet Il Mdefee East	1.85	IMPROVE	PRUNE-1	-	-	2017
			Sahlet Il Tahta	1.03	IMPROVE	PRUNE-1	-	-	2017
3	1	16.06	Arid Il Masriyeh	7.53	REGENERATE	PRUNE-2	PLANT-7	2023	2023
			Chwar Il Khasfe	1.48	REGENERATE	PRUNE-2	PLANT-7	2023	2023
			Mantaet Il Malaab/Il Chahara	7.05	REGENERATE	PRUNE-2	PLANT-7	2024	2024

**Area in ha – HB: Harvesting Block - PR: PRUNING – PL: Planting*

MU	Zone	Area MU*	HB name	Area HB*	Prescription	PR priority	Treatment	PL Year	PR Year
4	1	7.51	Beit Il Lik East	6.05	REGENERATE	PRUNE-2	PLANT-8	2024	2024
			Beit Il Lik West/ Douwarit Il Zaaroura	1.45	REGENERATE	PRUNE-2	PLANT-8	2024	2024
5	1	4.73	Arid Il Ziz/Jal Il Nea	1.64	REGENERATE	PRUNE-1	PLANT-1	2016	2016
			Berdesh	3.09	REGENERATE	PRUNE-1	PLANT-1	2016	2016
6	2	9.68	Hbayta/ Il Riheneh/ Baydar Il Ramel East	9.68	IMPROVE	PRUNE-1	-	-	2016
7	2	12.76	Aber Nefle/ Maeyil/Harf Il Aawaj/ Seeyit Il Ghamika East	11.91	REGENERATE	PRUNE-1	PLANT-2	2017	2017
			Bou Hamad Tahet Il Tarik East	0.85	REGENERATE	PRUNE-1	PLANT-2	2016	2016
8	2	16.71	Aber Nefle/ Maeyil/Harf Il Aawaj/ Seeyit Il Ghamika West	13.69	REGENERATE	PRUNE-1	PLANT-3	2018	2018
			Bou Hamad Tahet Il Tarik West	3.02	REGENERATE	PRUNE-1	PLANT-3	2019	2019

**Area in ha – HB: Harvesting Block - PR: PRUNING – PL: Planting*

MU	Zone	Area MU*	HB name	Area HB*	Prescription	PR priority	Treatment	PL Year	PR Year
9	3	9.86	Bou Hamad Fok Il Tarik North	8.35	IMPROVE	PRUNE-1	-	-	2018
			Bou Hamad Fok Il Tarik South	1.51	IMPROVE	PRUNE-1	-	-	2018
10	3	6.84	Manzaleh North/ Ahwet Il Hadid	6.84	IMPROVE	PRUNE-1	THIN	-	2019
11	3	6.54	Il Maramel	6.54	IMPROVE	PRUNE-2	-	-	2021
12	3	17.53	Jisr Il Wateh West	10.57	REGENERATE	PRUNE-1	PLANT-4	2019	2019
			Arid Il Souriyyin South	6.96	REGENERATE	PRUNE-1	PLANT-4	2020	2020
13	3	18.04	Il Yatoun/ Ketf Il Sahleh Il Fawaa South	11.75	IMPROVE	PRUNE-2	-	-	2022
			Arid Il Souriyyin North	6.30	IMPROVE	PRUNE-2	-	-	2024
14	3	18.72	Il Nabaa/ Sakhrit Il Wawiyyeh	4.40	IMPROVE	PRUNE-2	-	-	2025
			Mantaet Il Riheneh South	2.94	IMPROVE	PRUNE-2	-	-	2025
			Il Sahleh Il Fawka North	6.39	IMPROVE	PRUNE-2	-	-	2025
			Mantaet Il Riheneh North	4.98	IMPROVE	PRUNE-2	-	-	2025

**Area in ha – HB: Harvesting Block - PR: PRUNING – PL: Planting*

MU	Zone	Area MU*	HB name	Area HB*	Prescription	PR priority	Treatment	PL Year	PR Year
15	3	13.17	Mantaet Khezzen/ Baydar Ramel/ Mhattet Tekrir	13.17	IMPROVE	PRUNE-2	-	-	2023
16	2	2.72	Maison De La Foret South	2.72	RECREATION	PRUNE	SPECIFIC	2016	2016
17	2	19.16	Il Meghrayaa	7.85	REGENERATE	PRUNE-2	PLANT-5	2021	2021
			Arid Il Sabaa	5.24	REGENERATE	PRUNE-2	PLANT-5	2021	2021
			Jisr Il Wateh East	1.68	REGENERATE	PRUNE-2	PLANT-5	2020	2020
			Nabeit Bou Khalil/ Megrayit Bou Khalil	4.38	REGENERATE	PRUNE-2	PLANT-5	2020	2020
18	2	11.12	Hbayta/ Il Riheneh/ Baydar Il Ramel West	11.12	REGENERATE	PRUNE-2	PLANT-6	2022	2022
Total Area		210.95		210.95					

**Area in ha – HB: Harvesting Block - PR: PRUNING – PL: Planting*

Priorities for pruning are set based on field evidences (in the plots) of recent pruning, and the planned planting year. No records on previous operations were available to aid the temporal frame of decision-making. Planting should always follow pruning and the associated clearing of shrubs to avoid disturbance to seedlings for at least the 10 years after the plantation date. Selected MUs for planting are identified based on low density (especially MU-5), older age or larger height/diameter, reduced growth of trees (diameter increments), recent wildfires (to help in recovering the fire affected site) and spatial proximity (to reduce costs).

Thinning is tentatively proposed in MU-10 with a tree density over 300 trees/ha with a prescription IMPROVE by thinning in the same year it is thinned. A small amount of trees would be cut (3 trees/ha), by selecting them with sanitary/phenotypical criteria (unhealthy or bad shape trees, damaged, scarred). These fellings would greatly help developing the needed technical expertise for future thinning in Bkessine. As a pilot activity, MU-10 may be thinned if approved by MOA in 2019, before planting, and at the same time that pruning is taking place.

Logistics on how to minimize disturbance to forests

The plan is to keep a "business as usual" forest management for the community, while introducing gradual changes over time. For instance, we accept traditional pruning for mature trees, but younger diametric classes should be treated differently, and in fact, non-photosynthetic branches should be removed (in the medium-term future) over trees with a wider crown and lower heights (though this depends on site index).

Disturbance to forest may be expected to be low if the proposed subsequent sequence of clearing (including thinning), pruning, and reforestation, is strictly respected. Given the wide accessibility of the forest, the recreational demands, and the annual pine cone harvesting, it is known that wildlife, habitats, ravines and flora will remain impacted.

The preservation of oak maquis (Quercus calliprinos, Q. infectoria, Q. cerris L.var. Pseudocerris), some of the existing Calabrian pine (Pinus brutia) trees and prickly Juniper (Juniperus oxycedrus), Syrian maple (Acer syriacum, common Arabic name: Al kaykab al souri), yellow hawthorn (Crataegus flavida, common Arabic name: Al zaarour al asfar) and sycamore (Platanus occidentalis, common Arabic name: Al delb) should be enforced in order to improve ecological conditions.

Hunting should be prohibited, or at least regulated and monitored (in case it will be permitted by law in the future). Signs of empty cartridges were excessively found throughout the forest while surveying the study area.

Cone harvests should consider that seedlings are needed to be maintained and protected. An organized harvesting should avoid harvesting in the most recently planted areas (the same year). Accordingly, the rate of success in plantation would be significantly increased.

Water and soil conservation actions are required to be undertaken in different MUs especially in MU-7, which experiencing severe erosion-related problems of geological origin. Recommendations for water and soil conservation actions surpass the scope of this Management Plan and require a specific assessment of watershed cover, and water circulation and channel conditions, in order to devise an engineering project conducive to slope stability through small dams for consolidation of current soil movements (landslides).

Equipment and labor requirements

As one of the goals of the Plan is to keep forest management practices as close as to current ways (for overall acceptance of the Plan and the future development of a culture for sustainable management), there are no requirements of novel or increased demands in terms of equipment or labor. However, the implementation of thinning or new pruning practices essentially requires specific training for forest workers and supervisors.

Harvesting work Schedule

Temporal organization of work is provided in Table 16 for the period 2016-2025, for each harvest/ prescription unit.

Taking into account existing legal constraint, all prescriptions/treatments are to be executed between September 15th and April 15th.

Harvesting cost estimation and technical resources

It is assumed that costs are kept to current levels for the next planning period. There is no estimation for thinning, as it has not been done before in the area, and it is not clear at this point if this optimal harvesting plan including thinning will be implemented. Thinning mature stone pine trees may be controversial for the community and the Municipality. For other treatments, tasks planned are described and quantified in Table 17.

Table 17. Treatments planned for 2016-2025 in Bkessine

Planting (10 ha/year)			Pruning (20 ha/year)			Thinning
Year	ha Treated	Trees planted	Year	ha Pruned	Trees pruned	Trees thinned
2016	8.30	5,187	2016	24	4,277	
2017	11.91	7,442	2017	20	4186	
2018	13.69	8,556	2018	24	4,390	
2019	13.59	8,495	2019	20	3,969	21
2020	13.03	8,142	2020	19	3,868	
2021	13.09	8,183	2021	20	4,867	
2022	11.12	6,952	2022	23	3,622	
2023	9.02	5,635	2023	22	4,600	
2024	14.55	9,095	2024	21	3,622	
2025	re-plant		2025	19	4,259	
Totals	108.30	67,687		211	41,661	21

Pruning precedes always planting, so per unit costs should be added by ha every year. According to Table 17, and based on the costs provided by the Municipality during the field visits, the required investment for pruning every year ranges between 66.657 and 87.488 Million LBP (small trees cost 16,000 LBP - approx. 10.6 USD - and large trees cost 21,000 LBP – approx. 14 USD). This remains within the current budget available in the Reforestation Fund of the MOA (100 Million LBP from former year auctions). An approximate 50% of the forest can be regenerated artificially under this scheme in ten years, requiring 5,000-9,000 trees produced at the nursery and planted per year (650 trees/ha, 4x4 m layout). As the nursery produces 40,000 seedlings per year, this should be feasible. In 2025, the forest is evaluated for regeneration success and re-planting can take place as needed. More specifically, the financial and technical resources were established for the "Pruning" and "Planting" prescriptions. In both cases, minimal costs were evaluated.

Pruning activities

In general, the pruning activities will require three different teams, the first for pruning of trees, the second for pruning understory and cleaning, and the third for transportation of residues. Each tree will require three workers. On average, the total number of trees pruned per day and per team can reach up to 25 for small-sized trees, 10 for medium-sized ones, and 3 to 5 for large-sized trees (in reference to personal communication with representatives from the Municipality of Bkessine).

The unit costs of pruning of trees, cleaning understory and transporting residues were provided by representatives of the Municipality of Bkessine during the field visits (Table 18).

Table 18. Cost of pruning, cleaning, and transportation per tree

Tree Size	Cost of pruning/ cleaning/transportation per tree (LBP)
Small	16,000*
Large	21,000*

**Data from field visits*

According to the prescriptions defined for Bkessine, a total number of 41,661 trees are to be pruned over a period of 10 years (years 2016 to 2025), leading to a total cost ranging between 66.658 to 87.488 Million LBP as shown in Table 19.

Table 19. Total cost of pruning, cleaning, and transportation

Costs (LBP)	Total cost of pruning/ cleaning/transportation over a period of 10 years	Total cost of pruning/ cleaning/transportation per year
Lower cost limit	666,576,629	66,657,663
Upper cost limit	874,881,826	87,488,183

Planting activities

The total number of trees to be planted over a period of 9 years (2016-2024) was evaluated to 67,687 trees. In this work, only costs of purchasing the seedlings, labors for land preparation, and labors for planting were estimated (Table 20).

Table 20. Unit cost for planting one tree in LBP

Cost of 1 seedling	Labor for the preparation of land (digging 1 hole)	Labor for planting
1348.08*	2,782.29*	667.8*

**Data from field visits*

Two scenarios were then considered for the evaluation of the total costs for the planting period 2016-2024. The first one includes the cost of seedlings which can be purchased from the Nursery: 5,000-9,000 are to be planted per year and the nursery produces approximately 40,000 trees/year.

The second scenario that was evaluated considers that the seedlings are provided free of charge to the Municipality of Bkessine. The estimated total costs are provided in Table 21. However, the protection of seedlings from disturbances (e.g. fires, human activities, and grazing) should be secured by the Municipality.

Table 21. Total cost of planting in Bkessine

	Cost of seedlings	Labor for the preparation of land (digging holes)	Labor for planting	Total cost over a period of 9 years	Total cost per year
Scenario 1 - Including cost of seedlings	91,247,989.75	188,325,712.18	45,878,499.39	325,452,201.31	36,161,355.70
Scenario 2 - Excluding cost of seedlings		188,325,712.18	45,878,499.39	34,204,211.56	26,022,690.17

Overall, a total minimal for pruning and planting will range between 92.68 and 123.65 Million LBP per year, depending on the scenario and the average size of trees to be pruned.

It should be noted that for all financial calculations, the current cost was applied all over the planning period (i.e. 2016 to 2025) without taking into account inflation rate.

Procedures for monitoring and evaluating the harvest plans

The monitoring of regeneration success by the year 2025 is a critical aspect of Plan compliance. It requires an inventory of planted areas by simply counting survival rates in squared plots distributed in all planted MUs (i.e. 10x10 m should have at least 5-6 trees alive).

Controls for completely treated MUs are easier than those for small areas or individual trees. Consequently the proposed planning matches complete harvesting blocks with specific years of treatment. Table 22 shows the expected outputs in terms of biomass extracted every year if treatments are executed as planned for 2016-2025. Potential thinning residues of stone pine are not included.

Table 22. Biomass production by year in the Plan

Biomass/year (T)		
Year	Coarse	Fine
2016	29.84	479.88
2017	183.79	444.93
2018	504.55	605.87
2019	314.53	458.76
2020	282.96	425.97
2021	255.55	468.47
2022	173.47	437.76
2023	208.09	442.44
2024	153.58	357.39
2025	304.55	501.26

Biomass production controls are proposed to take place upon delivery to the plant of briquette production. Currently, production of firewood is evaluated through trucks capacity. In the future, a weighting of delivered biomass can be implemented in the back yard of the briquette plant. It is important though to keep all records of biomass production in a book note (associated with the implementation of the harvesting plan) for future use in evaluation of production. Presently, it was not possible to locate accurate data on previous years on harvesting, costs, yields, or previously treated locations.

Barriers, constraints, and challenges for further development

The necessary investments in planting and tending have to be guaranteed. The main challenge for this forest is primarily old age and lack of younger age classes, followed by other possible threats such as significant increase in tourism favored by the infrastructures being built.

Other possible threats are associated with chances that Leptoglossus sp. arrive to Bkessine, or undesired climate developments. Whatever new factors arise, it is critical that the forest improves in age class distribution and diversity of species, as it is the best strategy for unwanted changes mitigation.

Improvements in the forest require that the Plan will be implemented within an agreement between the Municipality and MOA and with the involvement of experts in the field and the supervision of the forest guards of the Ministry. As some actions/recommendations in this Plan are controversial or downright illegal, acceptance by the relevant authorities is needed. Removing trees with low production and improving the tree growth/production in MUs with densities over 300 trees/ha, for example, may encounter legal or administrative barriers.

List of Annexes (Bkessine)

Annex I. Map of the forest: management units and stands delineation
Annex II. Field protocol
Annex III. Field form for data collection
Annex IV. Completed field forms for the 44 plots in Bkessine
Annex V. Forest inventory: Forest characteristics by management unit detailed by diameter class and species-Averages per ha
Annex VI. Forest inventory: Forest characteristics by management unit detailed by diameter class and species-Total values
Annex VII. Prescriptions and treatments by harvesting block

ANDKET FOREST

6 Study Area and Dataset Description

Location of the study area

The village of Andket is situated in the administrative District of Akkar, North of Lebanon Figure 33. Its average elevation is 625 m above sea level and it is located 140 km away from Beirut city. The village extends to an approximate area of 27.16 km^2. The central coordinates of Andket are: 34°25'09.42"N and 36°18'45.80" E. It is bordered from the south by the town of Qobayat, from the west by Qobayat and Aidamoun, from the north by the two towns of Al Ouwaynat and Chadra, and from the east, by Akroum Mountain of the Western Mountain Chain of Lebanon. Andket is characterized by its large Calabrian pine (Pinus brutia) forest (the study area in this work) of 1,563.79 ha, representing about 20% of the village area.

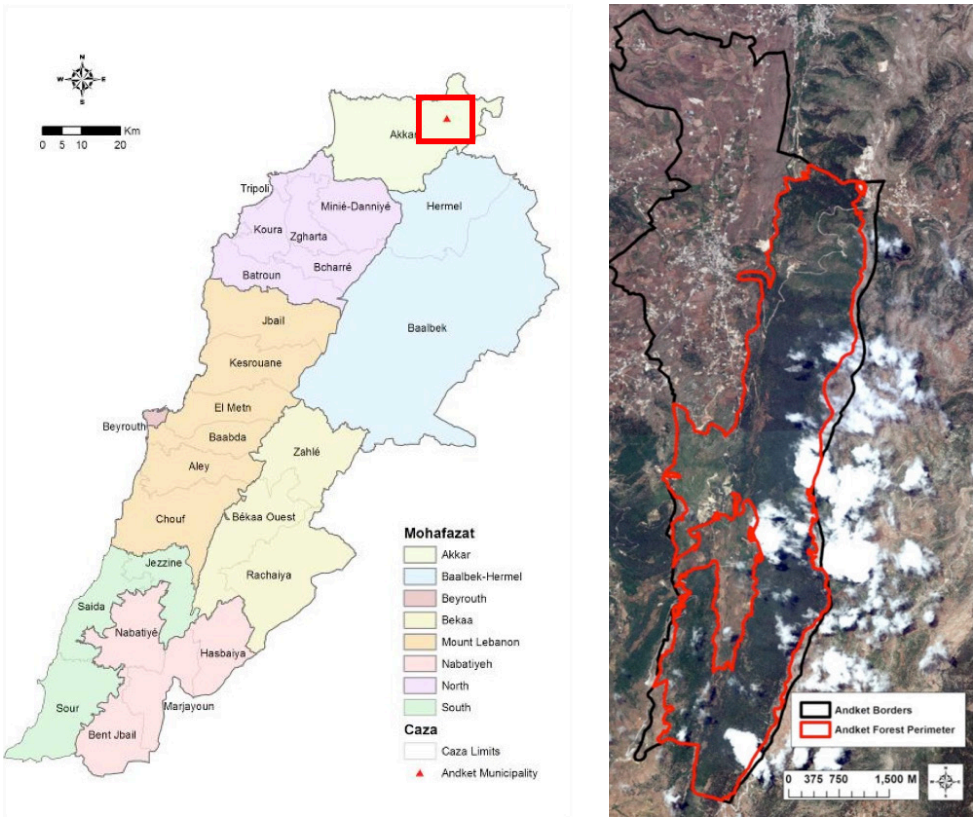


Figure 33. Location of the study area (left), and satellite imagery (Worldview) showing the extent of the study area including the Andket forest perimeter (light)

The pine forest of the Andket forest extends on both sides of Oudine valley. The main part of it extends over the eastern side of the Oudine valley, for about 9 km length in north-south direction and about 1.4 km width in east-west direction. A smaller part of the forest is located on the western side of the valley. The forest area is located between 419 m and 1,319 m above sea level. It consists of several narrow valleys oriented east-west in both valley sides. Steep slopes are mainly found in the southern part and in some places in the northern part of the main valley.

Biophysical characteristics of the study area

Climate

The annual precipitation rates in Andket ranges from 800 to 900 mm (MOE/UNDP, 2011). The rainfall is distributed between 4 and 5 months with an extended dry period lasting from March to October.

The mean annual temperature is about 15 degrees Celsius (°C) (MOE/UNDP, 2011). It might reach freezing temperatures in winter and 35 °C in a limited period of the hot season. During winter, the snow might cover the higher parts of the forest for about one month.

The forest is mostly protected from direct western wind. However, it is exposed to the humid south-west and the cold northern winds. Based on the national wind atlas for Lebanon, prepared by the United Nations for Development Program (UNDP) in 2011, the average wind speed in Andket, at 80 m above ground level, is of 7 to 8 m/s, possibly representing a potential renewable source for energy production. Storms have the potential of causing damages to the top pine trees in the forest.

Geology and soil

The soil of Andket Forest is almost homogenous and classified as red soil which developed on compact limestone. It is composed of decalcified residues of clay, which sometimes turns to brown forest soil. In some areas, basaltic soil is found. The depth of the soil is variable and can reach up to 45 – 50 cm mainly in the central part and lower altitudes of the forest. The northern and southern parts of the forest are characterized by quite shallow soils. In the eastern part, especially at high altitude, rocky outcrops exist and limit the growth of trees (CDR/GFA/EU, 2013).

Hydrology

One of the main characteristics of Andket Forest is the existence of perennial water resources. The main river, called “Naher el Mwaqid” in the north and “Naher Oudine” in the south, crosses the forest in south-north direction. Furthermore, the area has more than fifteen other streams that flow through the forest towards the main river. In addition, several water sources exist inside the forest. The two main water springs are known as “Nabaa el Charqi” and “Nabaa el Gharbi”, the Eastern and Western springs, which traverse the eastern and western part of the forest. There are no studies available on the water flow of these sources and springs, but it seems that the Eastern Spring is the richest among all of them and its water is canalized for irrigation purposes. The main part of the watershed area is covered by Andket Forest (CDR/GFA/EU, 2013).

Location of the study area

History

Andket Forest is a heritage asset of the village. It is a natural forest, mainly composed of native Calabrian pine trees (Pinus brutia), forming a single overstory layer; it is also occupied by a second layer of oak trees (Quercus calliprinos), forming the understory. However, no data for its emergence is recorded, although, it is known in history that trees were harvested for the railway construction in the 1940s.

Woodland types

The main tree species growing in Andket Forest is Pinus brutia Figure 34. Quercus calliprinos is growing as a second tree layer all over the western side of the forest (exposed to the west). Arbutus sp. is relatively abundant in the humid valleys and associated with Asplenium species. Arbutus seems to find good conditions for development and regeneration. Phylleria media, Rhamnus punctata, Pistachia sp. and Ceratonia siliqua are found at the lower parts of the forest. On the western side of the river (exposed to the east), Quercus calliprinos shows a dominant growth and is associated with Cupressus sempervirens in some places. Cupressus trees are characterized by their straight stem shape. Close to the river, riparian trees are growing such as Platanus sp. However, this part of the forest was not studied in detail since it is mostly private and used for agricultural purposes.

Figure 34. Pinus brutia forest in Andket

The main shrub species found in almost all the forest areas are Calycotome villosa, Poterium spinosum, Ruscus aculeatus. In general, the ground flora of Andket Forest is characteristic for the EU-Mediterranean vegetation level. Obviously, it was not possible to conduct a comprehensive inventory of this flora during three weeks at the end of summer season. However, at time of the survey some important species, such as Urginea maritimum which is growing in the open areas located between agricultural and forest lands, and Origanum libanoticum which is also found in the lower part of the forest, were noticed. Other species recorded were Origanum syriacum, Slavia sp., and Phlomis sp. (CDR/GFA/EU, 2013). Being a continuous and a non-fragmented area, Andket forest is very rich in fauna biodiversity, presenting several species of wild animals (fox, hyena, hedgehog, wolf, porcupine, wild boar) and reptiles. It also receives many migrating birds, such as bee-eaters, buzzards and swallows.

Fuel types

The Firelab[10] web application developed by the BP-IOE-UOB in 2014 shows the distribution of fuel types per village (Mitri et al. 2014). Accordingly, Andket is characterized by large areas (920 Ha) of fuel type 6 and 7 which represent tree stands with medium to high shrub cover (Figure 35) resulting in high combustibility of the forest. Several threats to the Andket forest are present. These include, fires, illegal tree logging for heating purposes, and clearing of forest land for the expansion of the agricultural surfaces by the private land owners.

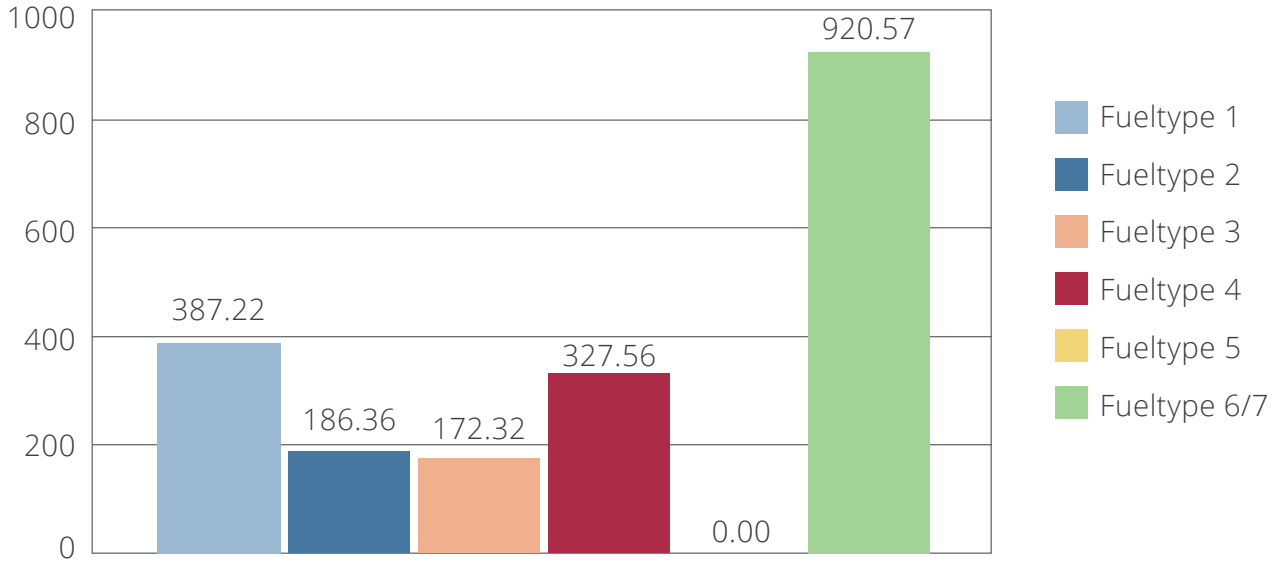


Figure 35. Distribution of fuel type areas in Andket (Ha)

[10] *http://ioe-firelab.balamand.edu.lb/*

However, the main persistent problem remains the danger of forest fires. Between 2000 and 2013, at least 9 fire events were recorded as per consultation of the Firelab web application tool (Mitri et al. 2014), affecting around 267 ha of the forest area Figure 36.

In 2007, a relatively large fire burned around 130 ha of the forest. Due to the highly dense vegetation cover, the fire couldn't be put down until there was change in wind direction. The current state of burned forest, observed during a field visit in February 2015, showed a high recovery of oak shrubs and to a lesser extent of pine seedlings. The large forest fires in Andket have had an increasingly devastating impact on the forest over the last decade. The forest is particularly vulnerable to forest fires and to their impact because of high tree density vegetation cover stretching on a terrain of steep slopes.

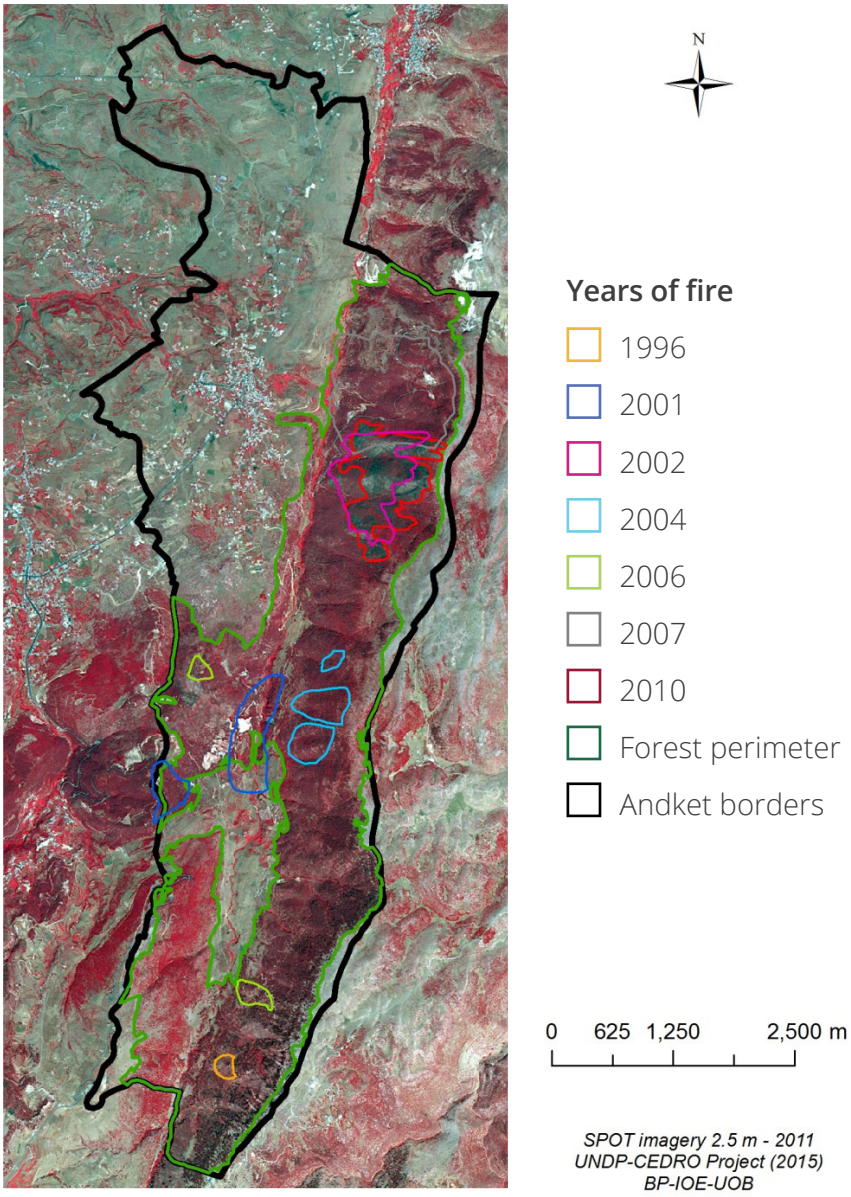


Figure 36. Perimeters of burned areas in Andket forest

Dataset description

Data collection for the inventory and management plan in Andket was conducted using the following tools and sources (Table 23):

- Literature reviews of previous studies and relevant information
- Satellite Imagery, topographic maps, and GIS data for the mapping of forest stands, roads, rivers, management units
- Field visits for field collection
- Personal communications and surveys for further extraction of data and information

Table 23. Types of data and sources used for data collection

Type of data	Source
National Reports	• National forest Law (1949) and other legal documents • Mission report: Elaboration of management plans of two pine forests in view of sustainable forest management and forest fire protection (CDR/GFA/EU, 2013) • FireLab Andket Village Report (UOB, 2015) • Lebanon's National Strategy for forest fire management (Decision No. 52/2009) • National forest Resources assessment reports (FAO 2005, 2010)
Scientific articles and papers	• De-Miguel, S. et al. (2014) • Palahí, M., S. et al. (2008) • Shater, Z., S. et al. (2011) • Hadaet-Obeyed, M. (2014) • Zianis, D., et al. (2011) • Hadaet-Obeyed, M. (2008) • Calama, R., et al. (2008) • Calama, R., et al. (2005) • Calama, R. and Montero, G. (2005) • Calama, R. and Montero, G. (2004) • García-Güemes, C., (1999) • García, C., et al. (2002) • García-Güemes, C., et al. (2001) • Madrigal, G., et al. (2009) • Manso, R., et al. (2014) • Pique-Nicolau, M., et al. (2011)
Satellite imagery	• SPOT Imagery (2.5 m) • WorldView Imagery

Type of data	Source
Maps	• Land Cover Land Use map of Lebanon of 1998 • Digital Elevation Model (DEM) of Lebanon (25 m) • Cadastral units map (CDR, 2005)
Inventory data	Field measurements in plots: • Species composition, cover and density, regeneration, health & general site condition • Tree distribution by diametric classes • Dominant trees diameter, height, growth (diameter increments), crown shape and wood condition
Surveys	Personal communications: Mr. Omar Massoud (President of Andket Municipality) Mr. Marwan Jreij (Vice-President of Andket Municipality) Topographer in Andket Municipality Police and forest guard in Andket Municipality

Three field visits to Andket were conducted on the 24th of February 2015; the 4th of March 2015 and 16-17th April (Figure 37). The visits consisted of 1) the compilation of the available documents and previous studies through personal communications with the community and the municipality members, and 2) the collection of the general forest inventory data and the identification of the management units.

Figure 37. Data collection in Andket forest

ANDKET FOREST

7 Forest Inventory

General Forest Inventory

Scope of the inventory

The inventory encompassed Andket forest as delineated in the available cartographic sources provided by the ADELNORD Project (CDR/GFA/EU, 2013). The projection coordinate system is WGS84 UTM 37N. Andket forest covers 1564 ha of surface, ranging in elevation between 419 m and 1319 m above sea level. The Andket forest was initially divided into 9 MUs (Figure 38). The areas of MUs vary between 124.56 ha and 285.25 ha (Table 24). Nevertheless, no previous information on stand delimitation existed within the different MUs. Not all the forest is covered by trees (i.e. presence of rocky areas, agricultural lands, herbaceous pastures and shrublands with no interest in terms of firewood or biomass). Tree stands occupy the forest in a patchy mosaic distribution, differing very notably in terms of silvicultural characteristics. Some MUs do not present any interest since they are mostly covered by shrubby vegetation.

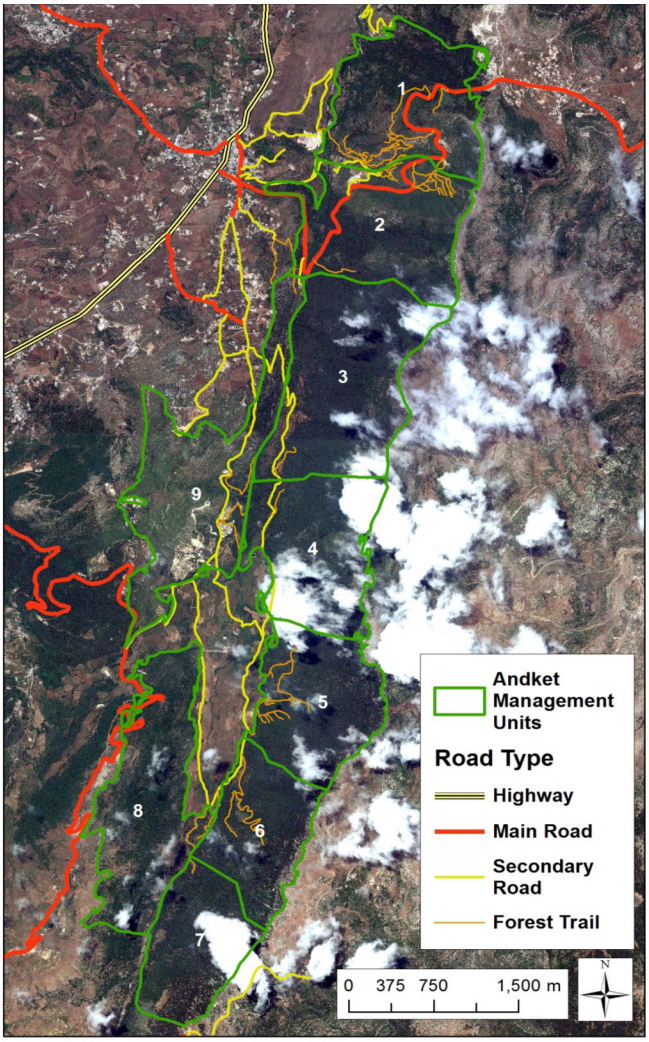


Figure 38. Adopted management units of Andket forest (CDR/GFA/EU 2013)

Table 24. Surface of the management units (MU) in Andket forest

Management Units (MU)	Surface (ha)
1	285.25
2	222.81
3	146.79
4	143.89
5	124.56
6	161.06
7	139.51
8	177.74
9	162.18

LULC classes and forest stand delimitation and mapping

Andket forest area is covered by different land use-land cover classes (LULCs) that have been classified in twelve categories (Table 25). According to the potential management for biomass and firewood production, it is essential to discriminate between forested and non-forested areas, since non-forested areas do not currently contribute to biomass production. Non forested areas (i.e. 1, 2, 3, 4, 10, 11 and 12) will be excluded in the biomass and firewood estimations of the forest.

In this Management Plan we focus on forested areas (classes 5-9), but in some cases (i.e. herbaceous pastures), non-forested areas could be afforested, and therefore, positively contributing to medium-term biomass production of the forest. Riparian vegetation is considered non-productive, as it should be preserved for biodiversity and hydrological protection.

Table 25. List of LULCs within Andket forest

Legend	LULC	Area (ha)
1	Rocky areas	148.46
2	Agricultural lands	35.516
3	Herbaceous pastures	86.71
4	Low shrublands	263.79
5	Low-medium shrublands and thicket stage forest	221.34
6	Medium-high shrublands with seed trees	251.96
7	Low pole stage forest	68.38
8	High pole stage forest	245.28
9	Uneven aged forest	202.81
10	Riparian vegetation	18.74
11	Roads	9.87
12	Forest tracks	10.94

Within the forested areas, there is a need to conduct a second sub-division in which the different tree stands should be identified. Stand delimitation is a necessary step for forest management. The aim of the forest stand delimitation is the definition of the minimum inventory and management unit areas presenting homogeneous silvicultural characteristics related to specific goals (i.e. biomass production). It is usually done in four phases:

1. Digitizing a preliminary stand delimitation based on available geospatial information
2. Conducting field sampling in the different tree stand typologies
3. Characterizing the different main stand typologies as well as the approving /modifying the preliminary stand delimitation
4. Producing the final map production with the biomass estimates for the whole stands within the forest

Additionally, the final map should be also reviewed and approved by the local forest stewards responsible of the treatments and future forest monitoring. The delimitation is designed to be as permanent as possible over time. The main criteria and corresponding data used for stand delimitation in Andket were the following (Table 26):

a. Site index (SI). This is the stands´ biomass growth potential, it is species-specific and usually measured in classes or ranges that refer to average net annual growth (m^3/ha year) or stand dominant height at a certain age. As this information was not available in cartographic format for Andket forest, we inferred a site quality by classifying areas presenting different aspect (i.e. north facing slope vs. south facing slope areas) and slope (indirectly related with soil depth, and, hence, to SI). Topographic differences are relevant in terms of radiation and available water in the Mediterranean basin, where there is at least one discernible deficit period during the year (summer). In places with an important altitudinal gradient, changes in elevation can also be an important factor to be considered. Also, current tree cover may provide insight on site quality. The inventory information gathered from field sampling was used to assess the quality.

b. Land features, physiographic limits and infrastructures (LP). Stands need to be easily recognizable in the field and limits should be stable over time to allow for future forest monitoring. For that reason, rivers, topographic break lines (e.g. mountain tops and ridges) and roads are usually good permanent border lines to be considered. Cartographic sources of infrastructures (i.e. roads and forest tracks), rivers and contour lines at medium-fine scales (changes in slope) are usually set as reference. In this forest, contour line maps were generated from the digital elevation model (DEM) using GIS tools, as well as the complementary slope and aspect 25 m resolution maps. Moreover, the previous Management Unit delimitation (Figure 38) was also taken into account as conditioning stand limit.

c. Tree cover (TC). It is the proportion of the surface covered by tree crown projections, usually expressed as a percentage of the total surface (%), also known as canopy cover (cc). It is related with tree density, stand growth stage, previous management, soil depth (limiting factor in rocky areas) and natural disturbances. It is usually estimated visually with satellite imagery and using GIS tools. In this case, satellite imagery composites were accounted (i.e. WorldView and SPOT imagery). We considered major tree cover class types for stand delimitation: no tree cover ($cc < 20\%$); sparse/incomplete tree cover ($20\% \leq cc \leq 60\%$); intermediate to total tree cover ($60\% \leq cc \leq 100\%$).

d. Species composition (SC). We have to consider the dominant species and accompanying or non-target species in the understory since the silvicultural treatments (i.e. thinning prescriptions and selected stand regeneration method) need to be in agreement with species requirements. This information was mainly acquired in the field, but previous data was available from the study by ADELNORD Project. In Andket forest, the almost unique dominant tree species is Pinus brutia. In some MUs there is no tree cover and the main vegetation is composed by Mediterranean maquis shrubland (i.e. MU 8 and 9). In some recently burned areas the conifer tree cover was replaced by resprouting shrublands (e.g. burned areas in MU1 in 2007).

e. Stand structure (ST). ST refers to the tree distribution per diametric classes. We classified the tree stands into even-aged, uneven-aged and two-story stands. Structure might be directly related with older forestry operations in other locations in Lebanon, but in Andket the recent occurrence of disturbances causing tree mortality (fires) explains the current age class structure of the forest. For delimitation purposes, model forest typologies with different stand structures were evaluated and digitized on screen from images (WorldView and SPOT), and later matched to a standard characterization developed from plots in a field survey directed to representative areas. Stand structure was considered as stand delimiting criteria only when spatial changes in stand structure were relevant.

e. Minimum stand area. It is the minimum inventory and management reference surface considered in the stand delineation digitalization process, usually 5-10 ha. This is a management-set lower limit based on forest goals, previously available spatial data, and human resources for management. However, if forest cover within stands is heterogeneous, smaller units may be digitized for improved yield estimation, but these will not be considered to be permanent units and will homogenize with the application of the silvicultural prescriptions.

h. Stands of special interest (SS). They represent areas presenting some singular physical-biological or socioeconomic features (e.g. the presence of endangered species or other forest services than biomass production) which require independent management units. In these cases, the area may be smaller than the established minimum stand area. In Andket, we identified the riparian vegetation as special interest areas with singular characteristics that a priori are excluded from biomass production management. Nonetheless, some eventual silvicultural treatments (thinning) conducted to improve the health and stability, as well as river bed barrier clearings, might not be dismissed.

Table 26 shows the main parameters and data sources considered in stand delimitation. Overall, the base for screen digitizing were the SPOT & Worldview images with the forest perimeter, the previously developed MUs (ADLENORD Project), as well as the overlaying of infrastructures (roads and forest tracks), and terrain features (i.e. contour lines, aspect, elevation and slope maps).

Table 26. Main parameters and data sources considered in stand delimitation

Parameter (abbreviation)	Theme	Characteristics	Data source
Site index (SI)	Aspect	5 classes (N, E, S and W, and flat); 25 m	Forests_Aspect
	Slope	4 classes (<15, 15-30, 30-60 and >60); 25 m	Forests_Slope
	Elevation	DEM 25m	Forests_DEM
	Satellite imagery	1:5,000 scale	WorldView images
	Inventory data	Dominant height and age	Inventory data
Land features, physiographic limits and infrastructures (LP)	Rivers	1:5,000 scale	WorldView images
	Watersheds	25 m DEM derived	
	Contour map	25 m DEM derived	Contour.shp
	Road cartography		Roads.shp
	Forest tracks		Tracks.shp
	Forest boundaries		Boundaries.shp
Tree cover (TC)	Satellite imagery	1:5,000 scale	WorldView images
	Satellite imagery	SPOT 2,5 m	Forest_sub_img
Species composition (SC)	Satellite imagery	1:5,000 scale	WorldView images
	Satellite imagery	SPOT 2,5 m	Forest_sub.img
	Inventory data	Species composition (%)	Pre-inventory data
	Land use land-covers	Polygon feature information, dominant species	Land Cover (1998)
Stand structure (ST)	Inventory data	Tree distribution in diametric classes	Inventory data
Stands of special interest (SS)	Recreation areas	1:5,000 scale	WorldView images

All the previous criteria and the available information considered, as well as the preliminary field visits, determined the following 5 forest typologies:

a. Low-medium shrublands and thicket stage forest (LULC class 5)

This category corresponds to dense shrubland that intermingles with dense thicket stage Pinus brutia regeneration (Figure 39).

Figure 39. General view of a low-medium shrublands and thicket stage forest (LULC class 5)

We can find scattered Pinus brutia seed trees in low densities (≤ 125 trees/ha), distributed into groups of 4-5 trees. The shrub cover is between 30 and 60 % cover and average height of 1.3 m. The soil can be shallow and rocky. Although these areas are occasionally located in the valley bottom clearings, they are more frequent in patches burned within the last 10-15 years, corresponding to the first natural succession stage of the vegetation in the gaps and clearings. Main shrub species are Juniperus sp. and Quercus calliprinus young coppice (post-fire sprouts). These areas lack of any management and present a difficult access; however, they might play an important role for some game species. They are considered of high fire hazard with no biomass potential.

b. Medium-high shrublands with seed trees (LULC class 6)

Correspond to the post-fire dense natural even aged Pinus brutia regeneration stands and many abandoned agricultural lands in valley bottoms (Figure 40).

Figure 40. General view of medium-high shrublands with seed trees (LULC class 6)

Dispersed mature (seed) trees present densities between 125 and 450 trees/ha. The regeneration densities are between 2,000 and 4,000 trees/ha and average diameter at breast height ≤ 7.5 cm. Quercus young coppice trees (diameter at breast height ≤ 10cm) can be also present in densities up to the 500 trees/ha. Shrub cover is higher than 60% and the average height is 2 m. The distribution of species is patchy, following burned area distribution within the last 20 years very clearly. This LULC can correspond to the natural succession of the Low-medium shrublands and thicket stage forest (LULC class 5). The only management is an occasional mature tree felling with only the trunk being extracted for firewood. This category represents a very high fire hazard with a very low biomass potential despite the high density of mainly young trees (there is a need to wait 10 to 15 years to start thinning while leaving seed trees for regeneration in case of a fire event).

c. Low pole stage Pinus brutia forest (LUCL class 7)

This category corresponds to the natural regeneration of the open and burned areas in the last 20-30 years (Figure 41). The densities are ≥ 1,500 trees/ha and average diameter at breast height about 10 cm. The canopy cover is higher than 60%. Shrubby species might be present but do not compete with the Pinus brutia regeneration. This category is characterized by a patchy distribution, and a very high fire hazard with a low current biomass value (biomass potential in 10-15 years).

Figure 41. General view of Low pole stage Pinus brutia forest (LUCL class 7)

d. High pole stage-young uneven-aged Pinus brutia forest (LULC class 8)

These areas have lower densities (≤ 1,500 trees/ha) and diameter at breast height about 15 cm (Figure 42). Canopy cover is higher than 80%. This is the natural succession of the low pole stage forests (LULC class 7). Stands tend to uneven aged structures in some cases, when regeneration intermingles with groups of mature trees and gaps created by wind blows or heavy snow. There is a presence of fallen dead trees, low stability, and dead trees on stand (i.e. suppressed trees). Gaps produced by fallen trees account for a 10 % of the area, which contains young seedlings in some cases. These areas are characterized by very high fire hazard, out of fire suppression capacity conditions. Likely active crown fire activity with spotting is expected in case wildfire occurs under extreme conditions. The sites represents medium to high biomass potential. The only current management focuses on cutting and harvesting the dead fallen trees.

Figure 42. General view of high pole stage-young uneven-aged Pinus brutia forest (LULC class 8)

e. Uneven-age mature Pinus brutia forest

This category corresponds to the natural succession of the high pole stage stands with gaps, in the unburned patches (or at least not burned with high intensities or recently), and to the oldest stands we have in the forest (Figure 43). These areas mainly appear in the vicinity of ravines in slopes and in fertile deep soils close to watercourses in valley bottoms (i.e. old agricultural terraces close to the river). Trees exhibit open crowns and diameters at breast height about 20 cm. However, tree density is usually not higher than 1,000 trees/ha; there is high variability in tree density within stands. The areas are characterized by medium to high biomass potential with a high canopy cover (>75%), some gaps are present within stands. Presence of fallen trees and dead trees was noticed. Low intensity frequent fires combined with livestock occasional grazing might have been the main modeling factors in those stands, as low intensity backfire causes a thinning-from-below effect, and killing the trees of the lowest diametric classes (<10 cm). The management is limited to fallen dead tree extraction.

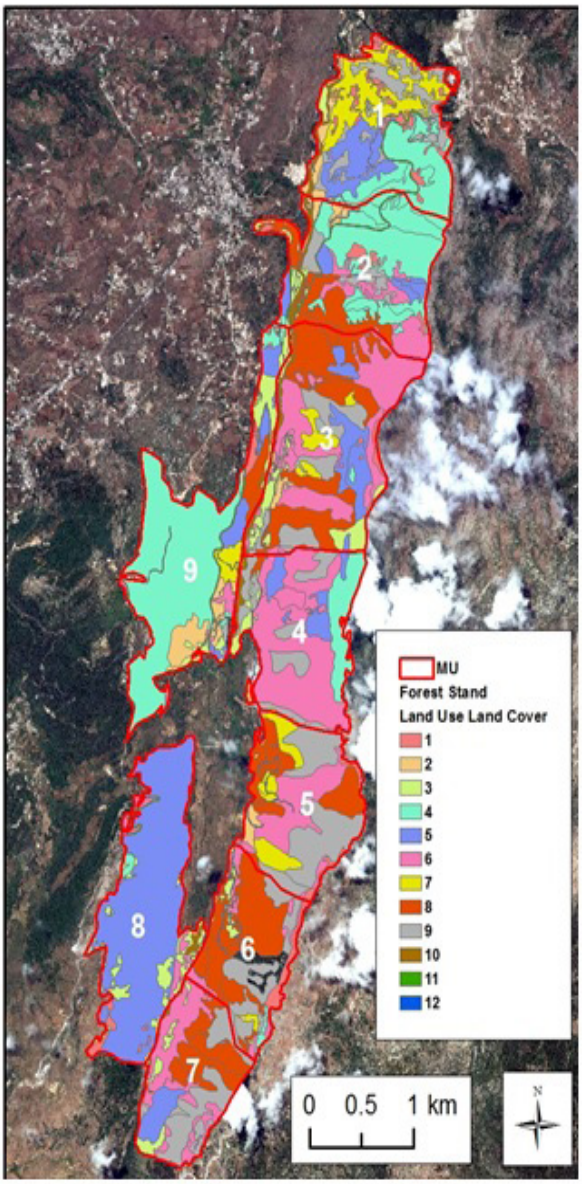
Figure 43. General view of Uneven-age mature Pinus brutia forest (LULC class 9)

After stand delimitation, the surface covered by the main LULC classes and the extent of the five forest typologies in the nine different MUs were estimated. The tree cover in the whole Andket forest extends over 63 % of the surface (Table 27). Figure 44 and Annex VIII include detailed maps of each MU and LULCs. One can notice the high stand variability within the MUs and the different wildfire events that caused stand patchy distribution (Figure 45).

Table 27. Areas covered in the nine MUs by the different LULCs and stand typologies in Andket forest

	LULC class surface (ha) within the different management units												
MU	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	71.83	15.72	4.15	99.64	6.83	3.54	35.97	4.66	30.09	5.43	4.41	2.99	285.25
2	1.34	-	23.29	19.26	14.89	56.00	-	81.52	22.34	2.62	1.17	0.39	222.81
3	2.49	1.82	15.02	-	18.50	37.85	8.41	34.18	23.28	4.47	-	0.76	146.79
4	-	0.88	3.96	20.92	19.54	73.03	-	1.59	19.91	3.07	-	0.98	143.89
5	2.81	1.31	0.64	-	-	28.19	16.46	26.76	46.83	-	-	1.55	124.56
6	54.82	-	7.36	9.10	-	5.85	1.28	50.73	28.15	1.44	-	2.33	161.06
7	8.81	1.96	7.75	-	10.27	40.67	-	37.08	31.50	1.33	-	0.14	139.51
8	2.79	13.82	13.30	112.92	9.39	4.33	6.26	8.76	0.73	0.37	3.27	1.79	177.74
9	3.56	-	11.22	1.95	141.92	2.50	-	-	-	-	1.02	-	162.18
Total	148.46	35.51	86.71	263.79	221.34	251.96	68.38	245.28	202.81	18.74	9.87	10.94	1,563.79

LULC types are: 1 = rocky areas; 2 = agricultural lands; 3 = herbaceous pastures; 4 = low shrublands; 5 = low-medium shrubland and thicket stage forest; 6 = medium-high shrubland with seed trees; 7 = Low pole stage; 8 = high pole stage; 9 = uneven aged forest; 10 = riparian vegetation; 11 = roads; 12= forest tracks.



Produced by the Biodiversity Program, Institute of the Environment, University of Balamand, Lebanon in partnership with University of Lleida, Spain
April 2015

Figure 44. The different LULC types per Management Units

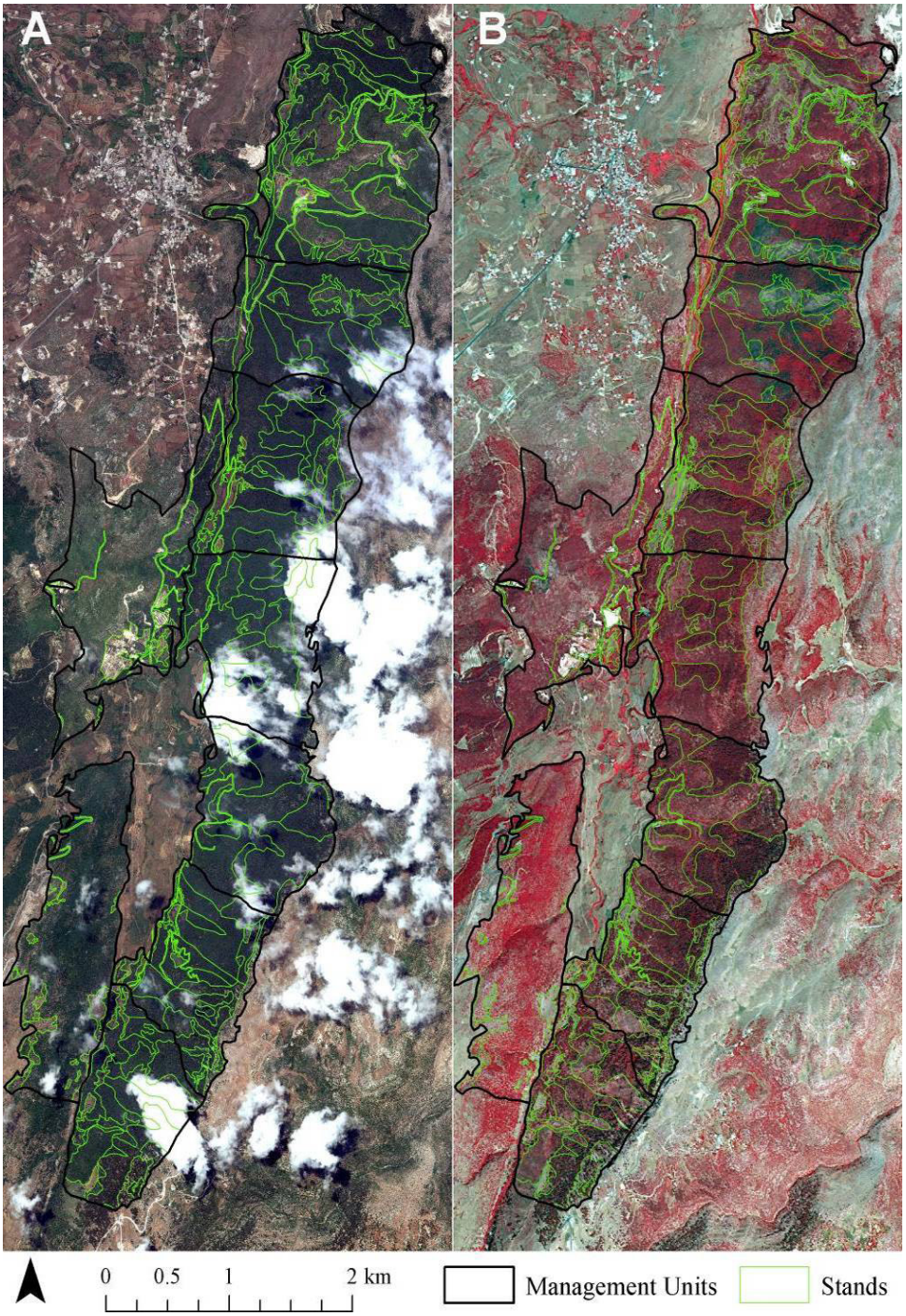


Figure 45. Forest typologies (LULCs) boundaries within the different MUs over the WorldView imagery (A) and SPOT imagery (B)

Field sampling: Accurate Forest Inventory

Given the extension of the forest and the difficult conditions for accessibility (Figure 46), the field work was conducted in a directed manner, and only representative areas of the previously described 6 forest typologies were evaluated. Plots layout was circular with fixed radius (between 10-15m, depending on tree density, as these are easier to layout and correct for slope)

Figure 46. General scene view of Andket forest (source: Mitri, G.)

A field survey protocol and measurement sheets for data collection were prepared and used in the field during the survey of March 2015, including basic dendrometric data (i.e. composition, density, diameters-DBH, height/dominant height, tree configuration, bark thickness, canopy cover, regeneration, health status, spatial distribution, sociological structure, dead and dying trees, etc.), and specific blocks for environmental values (i.e. ecological and biodiversity information, understory vegetation, dead wood, erosion, wildlife, unusual sp., and aesthetic value). The protocol and measurement sheet (field form) are attached as Annexes II and III. Three full equipment tools were used including 3 measuring tapes 30m long, 3 hypsometers Blume-Leiss (SUUNTO), one Vertex III, 3 standard metallic calipers and 3 bark thickness gauges. The 26 completed field forms for plots sampled in Andket are attached as Annex IX.

Stand site index

SI should be properly characterized in the areas were the harvesting will be carried out, after developing the accurate forest inventories for the biomass estimations. Determining the SI is a very important stand characteristic to plan the rotation temporal frame. However, it has been argued (de-Miguel et al. 2010) that SI in Lebanon may not be considered as a good indicator of true site quality as expected because heterogeneity caused by past treatments (thinning before 1991). Removing some dominant trees may have caused lower dominant heights being found in this study area than what is found in Syria, but also

conditions may be more arid due to the position in the Southern limit of the natural distribution of the species. Growth of P. brutia is linked to precipitation, which is 800-900 mm in this forest with a dry period of at least 5 months. So, quality is medium but roughly corresponds with topography in Andket, and better growth conditions are usually found downslope, in the lower northern exposition or flat areas.

Analysis of stand structure

The previous forest management plan (CDR/GFA/EU, 2013) proposed three general categories based on stand ages, and one mixed forest category. Based on the conducted analysis in this work using very high spatial resolution imagery, and after the development of the general forest inventories (26 sample plots), it was considered more accurate to keep the previously described five forest stand typologies for timber volume and biomass estimation. Plots acquired in the field were corrected for size, and were slope-corrected and their map-projected area was estimated. Forest typologies were described quantitatively from integration of field plot values (Table 28 and Figure 45).

Table 28. Tree different stand (shown as land use land-cover types LULC) main dasometric data

LULC	A	D	DBH	H	BA
1	148.46	0.00	0.00	0.00	0.00
2	35.51	0.00	0.00	0.00	0.00
3	86.71	0.00	0.00	0.00	0.00
4	263.79	0.00	0.00	0.00	0.00
5	221.34	110.00	17.33	9.62	2.97
6	251.96	320.04	20.31	10.58	12.75
7	68.38	1,841.10	11.45	7.40	20.34
8	245.28	1,532.57	15.64	9.01	33.45
9	202.81	839.89	19.01	10.13	29.83
10	18.74	0.00	0.00	0.00	0.00
11	9.87	0.00	0.00	0.00	0.00
12	10.94	0.00	0.00	0.00	0.00

The main stand dasometric data gathered are: DBH= diameter at breast height (cm); Havg= average tree height (m); D= tree density (trees ha-1); BA= basal area (m2 ha-1); A= area (ha). LULC types are: 1 = rocky areas; 2 = agricultural lands; 3 = herbaceous pastures; 4 = low shrublands; 5 = low-medium shrubland and thicket stage forest; 6 = medium-high shrubland with seed trees; 7 = Low pole stage; 8 = high pole stage; 9 = uneven aged forest; 10 = riparian vegetation; 11 = roads; 12= forest tracks.

Values in the next graphical representations (Figure 47) are given per ha, displaying tree density (N; trees/ha) and basal area (BA; m^2/ha) for the different diametric class (DC) distributions. This characterization serves as reference for future forest management. After the silvicultural system is defined for each typology and after delimitation of harvesting blocks, accurate estimates for biomass can be provided.

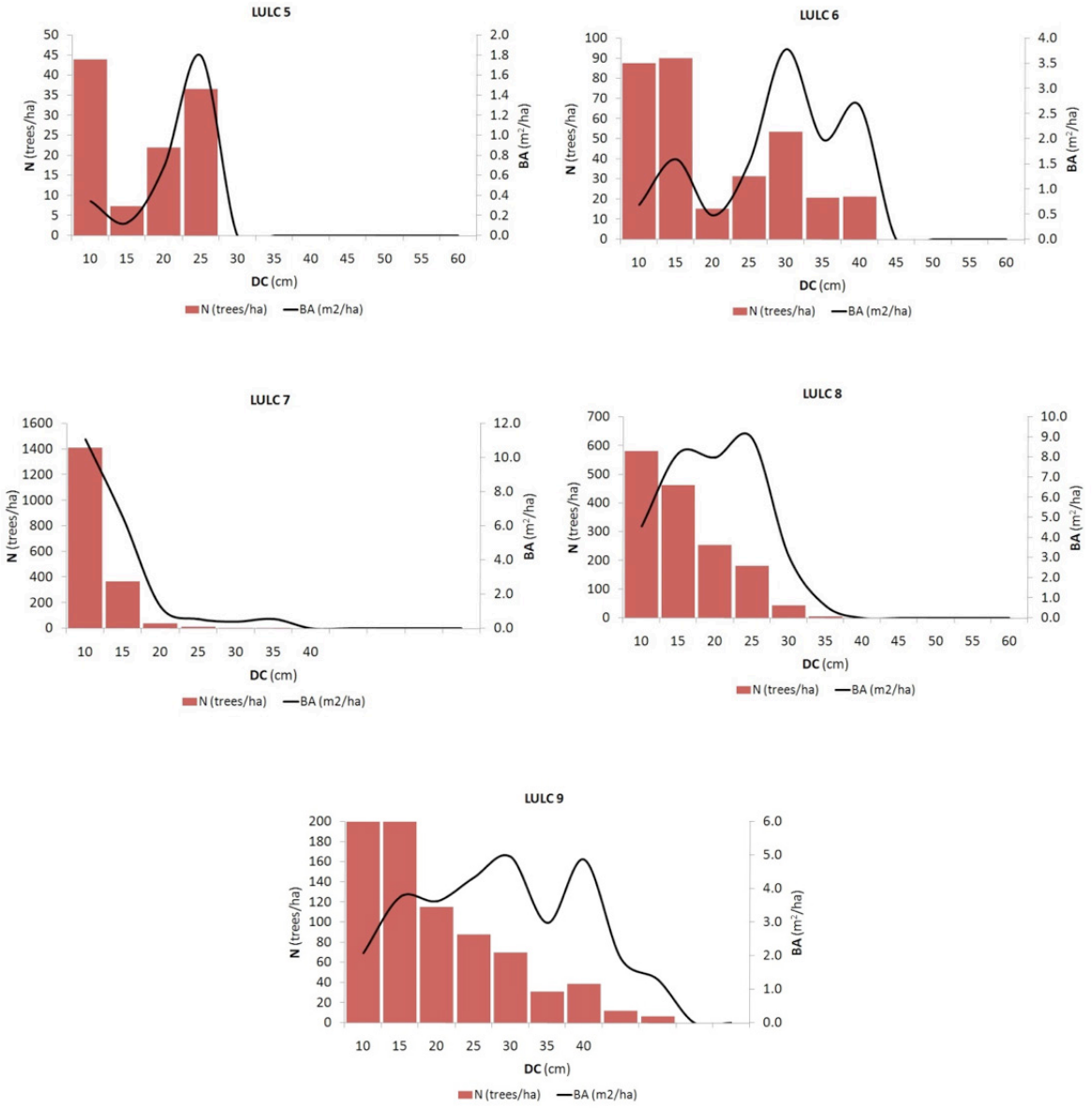


Figure 47. Diametric class (DBH) and basal area (BA) distributions for forest typology characterization

The spatial layout distribution of these typologies suggests a past history of fires burning the landscape in a patchy pattern that creates age differences and even-aged or uneven-aged structures, depending on fire intensity and fire frequency. Regeneration does not appear difficult in general, but recently burned areas (i.e. during 2007, 2012 years) do not show signs of Pinus brutia regeneration. This could be due to high fire frequency and a high fire severity. Signs of Thaumetopoea pityocampa and wood borer insects were not relevant. Some trees showed evidences of wind damage on tree crowns (broken branches). In some pole stage very high density areas (>3,000 trees/ha) the lack of treatments (thinning) induced a low stability in the stand and therefore high susceptibility to wind/snow damage (many broken trees); some evidences of wind/snow damage in certain patches were observed. Wood size quality is clearly affected by the lack of silvicultural treatments (thinning) in the last 25 years that induced the development of defective trunks, buddy tree conformation and thinner trees. Attending to the inventory results, we can conclude that Andket is a forest with potential for high growth, but threatened by lack of management, high intensity wildfires with high recurrence (less than 15 years, which replace P. brutia by shrubland with good sprouting traits), and with an insufficient infrastructure endowment (forest tracks) for the sustainable management (biomass harvesting) of the whole forest.

Diseases and pests do not seem to be an extensive problem in Andket, but not all the forest area was examined. Monitoring for Peridermium pini signs should be part of the future management. Both Thaumetopoea pytiocampa and Orthotomicus erosos are present, but there are no signs of large outbreaks. Should they occur (for instance from burned or felled wood) control is possible with trap trees or chemical /mechanical treatments.

Timber volume and biomass estimates

Plots acquired in the field were corrected for size, and were slope-corrected and their map-projected area was estimated. A plot-wise model for diameter-height relations was developed and applied to estimate the height of not-measured trees from DBH at the plot level (Figure 48).

Values found agree with the height model in Shater et al. (2011), supporting that these relations remain more or less similar in both Syria and Lebanon (de-Miguel et al. 2012a, 2012b).

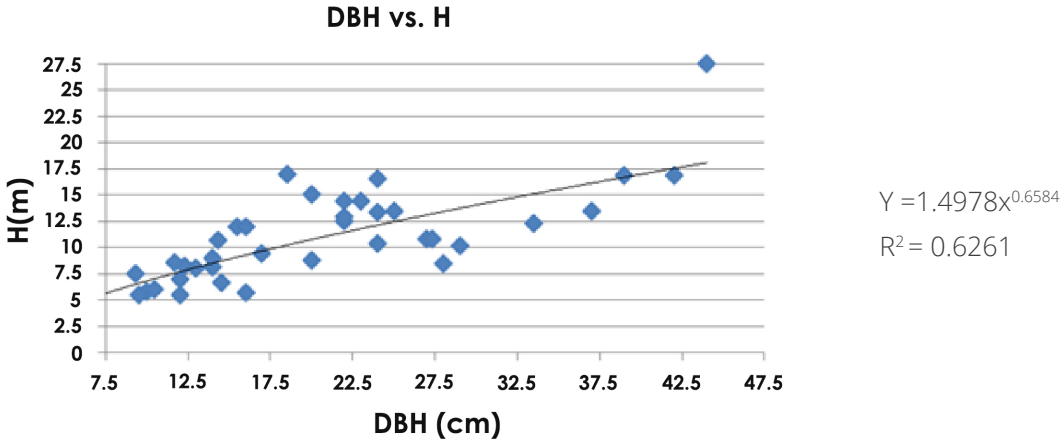


Figure 48. Plot-wise model for diameter-height relations

Dry biomass and timber volume estimates were done using individual tree equations that require the diameter at breast height (DBH) and the tree height (H). Gathered inventory data allowed estimating plot-wise timber volume and dry biomass in the main five forest typologies (Figure 47). Models developed for Pinus halepensis, the closest pine species to Pinus brutia in phenotype and ecological behavior (a hardy fast-growing pioneer), were used since no stem volume functions based on felled trees were available. Although Pinus halepensis is recognized as a separate species, botanists accepted in the past that Calabrian pine was a variety of Aleppo pine (Pinus halepensis Mill.) (Gezer 1985). The timber volume within stands for the different diametric classes was estimated using the following individual tree equation (Martínez et al. 1993):

$$V_{w.b.} = 0.0077186 \times d^{1.94631} \times h^{0.88012}$$

where $V_{w.b.}$ is the timber volume (dm^3) with bark on stand for a single tree with a d diameter at breast height with bark (cm) and h total tree height (m). Then, the timber volume in stands (m^3 w.b.; Table 29) was estimated from the tree density and the single tree volume at the different diametric classes.

Also individual tree dry biomass for two different fractions, coarse biomass for firewood (i.e. tree trunk and thick branches Ø > 2 cm) and fine biomass for the briquette plant (i.e. thin branches Ø ≤ 2 cm) was estimated from Montero et al. (2005); published equations used for Pinus brutia by de-Miguel et al. (2014) were taken from Montero et al. (2005), so the original equations which agreed well with the required separation of residues for firewood and the briquette plant in the Plan were also used.

$$B_C = (0.0816d^{2,133}) + (0.0784d^2 + (-1,9175d) + 14.207)$$

$$B_F = 0.0649d^{2.0349}$$

Where, BC is the dry coarse biomass (kg/tree), BF is the dry thin biomass (kg/tree), for a single tree with a d diameter at breast height with bark (cm) and h total tree height (m). As it was done before for the timber volume, the dry biomass for the different stand types was estimated considering the tree density from the different diametric classes.

However, it is recommended as a good practice to constantly calibrate the models (assess the possible over-underestimations) measuring timber volumes and biomass from the trees of the different diametric classes, fallen or occasionally removed from the forest (in the timber harvesting process), to estimate accuracies as an ongoing part of management.

Table 29. Timber volume and biomass estimations in the previously described tree stand typologies (Annex X)

LULC	V (m^3 /ha)	B_C (T/ha)	B_F (T/ha)	B_{TOT} (T/ha)
5	15	5.49	2.7	8.21
6	51	25.38	11.8	37.20
7	84	35.77	18.4	54.15
8	159	60.63	30.6	91.25
9	120	59.05	27.6	86.68

LULC types are: 5 = low-medium shrubland and thicket stage forest; 6 = medium-high shrubland with seed trees; 7 = Low pole stage; 8 = high pole stage; 9 = uneven aged forest. V = tree stem timber volume with bark; BC= coarse dry biomass, Ø > 2 cm; B_F= fine dry biomass Ø < 2 cm; B_{TOT}= B_C + B_F.

Computation of timber volumes and biomass within the Management Units

Taking into account the timber volume (Martínez et al. 1993) and dry biomass estimates for the different fractions (Montero et al. 2005) in the different stand typologies (Table 29), the total amount of dry biomass (BTOT) and timber volume with bark (V) stock available in the forest within the different Management Units were estimated (Table 30). This is an approximate gross estimation that should be improved in the future if the accessibility conditions of the forest advance and sustainable management are extended to other areas.

Table 30. Timber volume (V_{TOT} in m^3 wb) and dry biomass (B_{TOT} in T) in the Management Units of Andket forest (Annex XI)

MU	LULC	V (m^3)	B_T (T)	B_F (T)	B_C (T)
1	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	104.7	56.1	18.6	37.5
	6	181.7	131.7	41.9	89.9
	7	3005.7	1947.5	661.1	1,286.4
	8	741.9	425.5	142.8	282.7
	9	3,595.4	2,607.8	831.3	1776.6
	10	0.0	0.0	0.0	0.0
	11	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 1		**7,629.4**	**5,168.6**	**1,695.6**	**3,473.0**
2	1	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	228.4	122.3	40.6	81.7
	6	2,872.3	2,082.8	661.9	1,421.0
	8	12,971.3	7,438.7	2,496.6	4,942.0
	9	2,669.2	1,936.0	617.1	1,318.9
	10	0.0	0.0	0.0	0.0
	11	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 2		**18,741.2**	**11,579.8**	**3,816.2**	**7,763.6**

MU	LULC	V (m^3)	B_T (T)	B_F (T)	B_C (T)
3	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	5	283.7	151.9	50.4	101.5
	6	1,941.5	1,407.9	447.4	960.5
	7	702.8	455.4	154.6	300.8
	8	5,439.7	3,119.5	1,047.0	2,072.5
	9	2,782.0	2,017.9	643.2	1,374.6
	10	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
	11	0.0	0.0	0.0	0.0
Total MU 3		**11,149.7**	**7,152.5**	**2,342.6**	**4,809.9**
4	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	299.8	160.5	53.3	107.2
	6	3,745.8	2,716.3	863.1	1,853.1
	8	252.9	145.1	48.7	96.4
	9	2,379.6	1,726.0	550.2	1,175.8
	10	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 4		**6,678.1**	**4,747.8**	**1,515.3**	**3,232.5**
5	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	6	1,446.2	1,048.7	333.2	715.5
	7	1,375.4	891.2	302.5	588.7
	8	4,257.8	2,441.7	819.5	1,622.2
	9	5,596.0	4,058.9	1,293.8	2,765.1
	12	0.0	0.0	0.0	0.0
Total MU 5		**12,675.3**	**8,440.5**	**2,749.1**	**5,691.4**

MU	LULC	V (m^3)	B_T (T)	B_F (T)	B_C (T)
6	1	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	6	299.9	217.5	69.1	148.4
	7	107.3	69.5	23.6	45.9
	8	8,073.2	4,629.7	1,553.9	3,075.9
	9	3,363.6	2,439.7	777.7	1,662.0
	10	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 6		**11,844.0**	**7,356.4**	**2,424.2**	**4,932.1**
7	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	5	157.6	84.4	28.0	56.4
	6	2,085.9	1,512.6	480.7	1,031.9
	8	5,900.3	3,383.7	1,135.7	2,248.0
	9	3,764.8	2,730.7	870.4	1,860.2
	10	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 7		**11,908.7**	**7,711.3**	**2,514.8**	**5,196.6**
8	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	144.1	77.1	25.6	51.5
	6	222.1	161.0	51.2	109.9
	7	523.3	339.1	115.1	224.0
	8	1,393.6	799.2	268.2	531.0
	9	86.8	62.9	20.1	42.9
	10	0.0	0.0	0.0	0.0
	11	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0
Total MU 8		**2,369.8**	**1,439.3**	**480.1**	**959.2**

MU	LULC	V (m^3)	B_T (T)	B_F (T)	B_C (T)
9	1	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	2,177.2	1,165.5	386.8	778.7
	6	128.5	93.2	29.6	63.6
	11	0.0	0.0	0.0	0.0
Total MU 9		2,305.6	1,258.7	416.4	842.3
Total Andket forest		**85,301.9**	**54,854.9**	**17,954.2**	**36,900.6**

Results need to be considered only as a global reference value since the implementation of an intensive systematic inventory did not result a feasible option under the technical and time constraints of the project. Moreover, we have to consider that nowadays only the stand thinning biomass on the 20-50 m buffer area around the few existing forest trucks can be harvested, which is a minor part of the total biomass existing in the forest; Table 30 – Annex XI).

Accuracy assessment

Errors committed in the estimation of volume at the LULC level are well under 30% (Table 31), which is the upper limit in protective forests in other Mediterranean (i.e. Spain).

Table 31. Variables for estimation of volume error for the forest

Sampling Error for the forest		
Total Avg. Vol. P. brutia	100.48	m^3/ha
Standard deviation (m^3)	56.78	m^3/ha
Variation coefficient (%)	56.51	%
t student=	2	
Number inventory plots	26	plots
Sampling error (%)	22.16	%

ANDKET FOREST

8 Forest Management Plan

Current management status of the forest

The forest of Andket is mostly a communal land (Machaa) owned by the Municipality, however, it also contains some areas with private ownerships. Nevertheless, the forest was classified as a Green Area in the urban plan of Andket village, implying that construction is prohibited within the forest. During a field visit to Andket in February 2015, a personal communication with the topographer confirmed that a detailed cadastral map showing land ownership is in the process of being developed. A detailed cadastral map would avoid the enlargement of the surrounding agricultural lands and limits the fuelwood gathering activities in private areas leading to the fragmentation of the forest area.

Based on the latest numbers provided by the Municipality of Andket (personal communication, 2015), the village counts 6,000 registered individuals and 2,000 residents. The latter number increases during weekends, holidays and summer. The village is also hosting 500 Syrian refugees since the Syrian conflict outbreak. The dominant employments of Andket residents are soldiers in the army and owners of small businesses. Many individuals are army retired.

The forest provides many goods and services for the benefit of the community; however, no income-generating activities specifically in relation to the forest are currently taking place. The main activities related to the forest includes traditional fuelwood collection for heating purposes, collection of herbs and plants for culinary and medical purposes (i.e. Thymus sp. and Salvia sp.), hunting, grazing and recreation.

Current management activities

According to the Forest Law of 1949, MOA is the official authority through which permissions for the implementation of any silvicultural activities are issued; and the Municipality is the responsible body for the implementation of any required management activities, prescriptions or treatments.

Some of the Association for Forests, Development and Conservation (AFDC) achievements in the Andket forest together with the local unit and in collaboration with the Municipality comprised the creation and cleaning of buffer zones around agricultural lands, the establishment of firebreaks, and reforestation.

In the past few years, forest firefighting activities in Andket have been intensified. The Municipality of Andket and AFDC undertook several forest fire prevention and protection activities. These included regular cleaning of the forest bush-layer and floor from dead twigs and plant material near the edges of roads with a focus on the most frequented roads. However, these activities are currently only maintained in the private lands and not in the communal lands of the Municipality. In addition, the absence of accessible roads does not help undertaking such activities within dense forested areas; thus resulting in the accumulation of bushes in the forest understory which increases the risk.

The organization of regular patrols during the fire season through forest service, forest guards and local dwellers, has proven to be crucial for the early detection of the fire and fast intervention. The patrols together with awareness-raising among the villagers have reduced the number of forest fires during the last three years. According to the ADELNORD study (CDR/GFA/EU, 2013), Andket forest was found highly exposed to fire hazards due to the absence of sustainable management and fire protection and prevention plans.

Until today, Andket Forest has not been the subject to professional technical forest management plans and there aren't any current management activities other than those mentioned above. Non-target oriented thinning decreases the quality of remaining forest stand, including the reduction of timber quality to be harvested in the future.

Existing infrastructure

In the context of forest management, two forest centers were created in Andket. The first one is one of the 14 Forest Guards Centers created by MOA. The second center was created in 2009 by the Association for Forests, Development and Conservation (AFDC) within the project "Management and Sustainable Development of Forest Areas in Andket, North Lebanon" (Italian Cooperation funded project within ROSS II). The center operates on volunteering basis.

Some of the activities implemented by AFDC in collaboration with the local unit of Andket and the Municipality included the installation of water outlets, a water pond, and a helipad to support firefighting by helicopter. Andket has also been provided with a Toyota Land Cruiser HZJ-79 fire truck for earl intervention in firefighting. Its capacity is 400 liters and it is well equipped to be used for first firefighting interventions. The vehicle is stationed and maintained at the local AFDC unit in Andket. In addition, AFDC established a tree nursery in 2010, which produces 100,000 seedlings per year, as well as many medicinal and aromatic plants (AFDC, 2015).

In the current state, the accessibility to the forest is limited to only one main road in the Northern part where the disastrous fire in 2007 affected 130 ha of the forest. Other few secondary roads are adjacent to the agricultural lands passing through Oudine valley from North to South and which are only accessible by 4x4 vehicles especially in winter when they are flooded by rainwater (Figure 49). Some of these roads are extended on the forest slopes and on higher altitudes to form forest trails with foot accessibility to hikers, hunters and wood collectors.

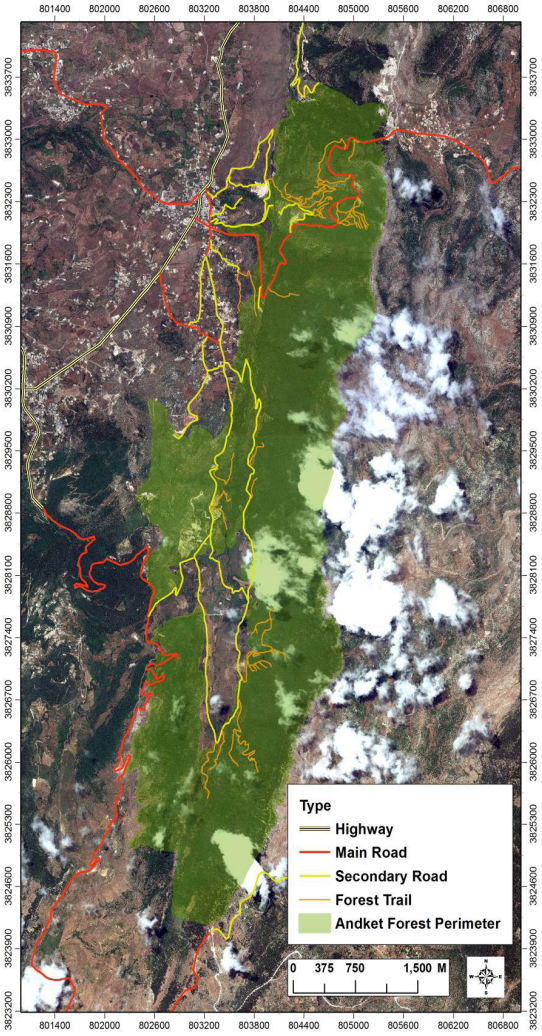


Figure 49. Extent of the study area and road accessibility

The Forest Management Plan (2016-2025)

Management objectives

The management objectives for Andket Forest need to ensure an improved forest structure and productivity. The goals include avoiding the loss and the anticipated irreversible degradation of additional areas of the forest, ensuring the improvement of its health, and supplying fuelwood for local communities and biomass for bioenergy production. As a result, the forest will be strengthened to fulfill short to long term economic, ecological and social functions.

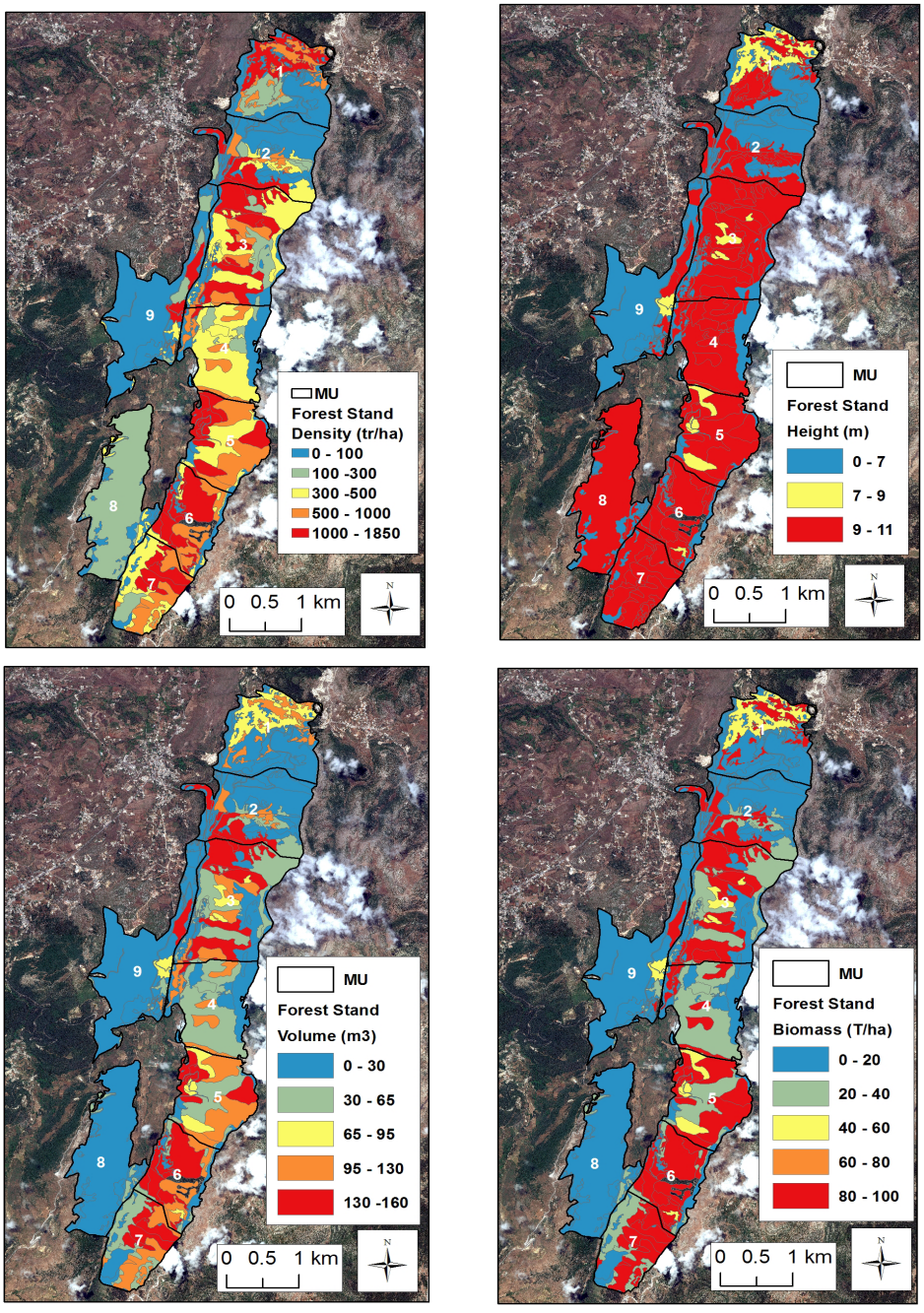
In this context, the Forest Management Plan for Andket can be structured into three categories: production of wood, conservation and protection, and recreational services (Table 32).

Table 32. Management objectives and their descriptions

Category	Objectives	Description	Priority
Production of wood	Objective 1: Biomass production for bioenergy	To implement silvicultural treatments for the production of biomass coming from residues harvested after pruning and thinning in the purpose of briquettes production.	Primary
Conservation and protection	Objective 2: Forest fire prevention	To develop effective measures intending to reduce fire vulnerability, to increase ecological and social resilience to fire, and to prevent the occurrence of harmful fires and unsustainable fire regimes.	Primary
	Objective 3: Protection of natural resources	To ensure the conservation and improvement of biodiversity, maintain the productivity of soil, and minimize the impact of forest practices on water quality.	Primary
Environmental Services and Social Promotion	Objective 4. Community engagement	To encourage the effective participation of the local community in the development of the forest management plan.	Secondary
	Objective 5. Maintenance and enhancement of recreation	To provide the public with recreation facilities, services, and information.	Secondary

Forest Management Units

As previously shown in the forest inventory, Andket forest is divided into 9 management units. The LULC types of forest stands in each management unit were identified and classified according to their density, average height, volume, and biomass quantities (Figure 50).



Produced by the Biodiversity Program, Institute of the Environment, University of Balamand, Lebanon
in partnership with University of Lleida, Spain
April 2015

Figure 50. Characteristics of forest stands per management unit

Each unit of the MUs is assigned to one or several objectives according to their characteristics in addition to other criteria such as proximity to roads, and ecotourism potential among others. In the purpose of achievement of the objectives, several prescriptions are suggested per MU and each prescription is related to a set of monitoring measures (indicators) and a priority for implementation (Table 33).

Table 33. Distribution of prescriptions and their associated indicators

Objectives	Prescriptions	Indicators	MUs
1	Prescriptions and treatments suggested for the achievement of Objective 1 are detailed in the Harvesting Plan in Chapter 9. The plan includes silvicultural treatments such as: • Pruning of tree branches provides biomass for briquettes production • Thinning of stands by selecting the high quality trees and removing damaged trees from weather or diseases • Clearing of corridors for the establishment of forest roads and cleaning the sides of the existing trails increasing the accessibility for biomass harvesting. • Provision of training workshops about sustainable forest management practices for biomass production	Quantities of biomass pruned (Tons per harvesting area) Number of trees thinned (per harvesting area) Maps of forest roads Number of attendees to workshops	Refer to chapter 9
2	Prescriptions shall coincide with those of Objective 1. Wildfire risk assessment: • Identifying fuel types, combustibility, topography, infrastructure and land uses (residential areas, industrial developments, recreational areas, public spaces, and dumpsites among others) within the forest (P2.1) • Producing detailed fire hazard map of the forest (P2.2) • Producing detailed fire vulnerability map of the forest (P2.3) • Producing detailed fire risk map of the forest (P2.4) Silvicultural treatments for forest fire prevention: • Pruning of trees and shrubs reduces the accumulated ladder fuels thus preventing fire spread (P2.5) • Creation of new firebreaks and fuelbreaks and cleaning the side of the existing forest trails (P2.6) • Thinning of high density stands prevents the spread of crown fires (P2.7)	Map of fire hazard Map of fire vulnerability Map of fire risk Total cleaned area for establishing a fire break Total treated area for establishing a fuel break Production of fuelwood form pruning and thinning in tons/year	All MUs

Objectives	Prescriptions	Indicators	MUs
3	To ensure the conservation and improvement of biodiversity, maintain the productivity of soil, and minimize the impact of forest practices on water quality (P3.1) To select planting areas and out-planting in fire affected areas with no tree regeneration (P3.2) To protect presence of several Quercus species (and other broadleaves) in the forest should be protected from treatments and to promote them whenever possible (P3.3) Note: P3.2 and P3.3 are further discussed in Chapter 9.	Provisions of a variety of forest cover and habitat (i.e. different aged forest stands, a variety of species, and forest openings) Measures taken to stabilize soil in eroded sandy areas Extent of planted areas Extent of protected areas of broadleaved species	All MUs Planting in areas with recent fires in MU1 and MU2
4	Training of the community involved in silvicultural activities for the implementation of the harvest plan (P4.1) Developing nature and forest management interpretation programmes (P4.2) Raising awareness campaigns for the local community about the benefits of sustainable forest management practices (P4.3)	Number of people trained in silvicultural activities Adopted nature and forest management interpretation programmes Number and dates of awareness activities and events held and number of awareness material produced and disseminated	All MUs
5	Maintaining the forest trails (P5.1) Maintaining camping areas (P5.2) Locating watch sites (P5.3) Disposing efficient garbage disposal system (P5.4) Protecting sites of aesthetic values (P5.5) Promoting responsible ecotourism activities in Andket (P5.6)	Distance of trails maintained Number of annual users of campers Number of watch sites established Number of placed garbage bins/ containers Number of protected and promoted monumental trees Protected streams and other visually appealing features	All MUs

Table 34. Description of stakeholders and beneficiaries of the management plan, their roles and responsibilities

Stakeholders/ beneficiaries	Management objectives	Roles and responsibilities
MOA	1 and 2	Provide necessary permits for silvicultural treatments such as pruning and thinning Provide effective monitoring and control of silvicultural treatments Provide technical support to the Municipality for the implementation of its plans for regeneration, plantation, and silvicultural treatments Ensure the proper implementation and enforcement of forest laws and regulations Provide flexible framework for the adoption of fire resilient forest cover
Municipality of Andket	1, 2, 3, 4, and 5	Manage the implementation of the forest management plan Manage the implementation of the forest harvest plan Ensure sufficient financial resources for the implementation of the forest management and harvesting plans Acquire all necessary permits and licenses for pruning and thinning activities in the forest Launch the tenders for pruning and thinning (if needed) Provide and operate necessary infrastructure/equipment for processing biomass residues Ensure adequacy and maintenance of forest infrastructures and installations Monitor the arrival and outbreak of certain pest and diseases that can affect trees Build the capacity of users about good practices on silvicultural treatment and fire management (in case they are allowed) based on the existing regulations. Develop agreements with companies/administration/privates responsible of forest infrastructures on the necessary investments and periodic works for their maintenance Monitor the proper use of recreational facilities Develop awareness campaigns about the fundamental role that the rural population plays in protecting the forest preventing dangerous fires Raise awareness to general public by posters and signposts which warn the public about the danger of forest fires which are placed at conspicuous places of roads, picnic and camping sites and villages

Stakeholders/ beneficiaries	Management objectives	Roles and responsibilities
Private land owners	2	Undertake responsible forest management practices and avoid fire risk activities within their properties
Pruning and thinning contractors	1 and 2	Familiarize themselves with the harvesting plan Ensure they are trained to properly implement activities suggested in the harvesting plan Undertake proper pruning and thinning techniques Ensure proper handling and disposal of pruning and thinning products
The local community of Andket	1, 2, 3, and 4	Involve aware individuals from the community to whom awareness raising and surveillance campaigns are addressed, in the awareness/education/surveillance actions.
Directorate of Civil Defense (Center of Andket)	2	Mobilize means of fire suppression Train individuals from the local community on forest firefighting
NGOs (e.g. AFDC) and the local unit of Andket	4 and 5	Contribute to the provision of support for community engagement
Visitors	5	Avoid the use of any source of fire within the forested area Undertake responsible recreational activities within the forested area

Financial and technical resources

Financial and technical resources for implementing the prescriptions of Objectives 1 and 3 (i.e. in relation to pruning, thinning including opening, and planting) are presented in the Forest Harvest Plan.

Constraints and obligations

The current legal framework in Lebanon prohibits trees cutting for biomass production. All necessary permits should be acquired for any future work in the forest. Accordingly, a detailed Memorandum of Understanding should be developed and adopted between the Municipality of Andket and MOA to allow for tree cutting and pruning within the framework of a clear harvesting plan.

Another constraint in Andket is the lack of accessibility to many parts of the forest and the topographic conditions of the forest make it very challenging to manage the entire forest cover.

In general, site quality is also diverse and dependent on topographic position, but environmental factors (climate, soils) indicate prospects are good for this forest.

ANDKET FOREST

9 Forest Harvest Plan

Scope of the Harvest Plan

This Forest Harvest Plan aims at supporting an improved decision-making with regard to pruning, and thinning the previously determined MUs.

Most forest management plans are designed for 10 years, and estimated increments are usually valid for 10 years. Accordingly, the planning period adopted here is also set for 10 years.

Generic scheme for silvicultural treatments of P. brutia stands in Andket

The variety of forest types in Andket calls for different silvicultural itineraries, but a general model can be envisioned for the predominant Pinus brutia component of Andket forest.

Main conditioning factors for the silvicultural treatments in Andket

Forest fires: There is a need to increase stand resistance to fire, which implies:

1. Thinning from below defined as the removal of emergent, intermediate and suppressed strata classes thus reducing ladder fuels and decreasing vulnerability of the forest to wildfires
2. Stand transformation from uneven aged to even aged structures
3. Low pruning (up to 2 m height) to reduce ladder fuels in strategic points (i.e. in ravine junctions and crest line junctions)
4. Extraction of the whole tree to reduce fuel load and fire hazard (without leaving cut branches in the forest)

Heavy snow: The cutting and extraction of broken trees is a priority during thinning.

Forest roads: The treatment of only the stands with appropriate forest road access.

Physical protection function in steep slopes: Management of the stands in steep slopes and higher elevations for them to achieve their protective functions in terms of reduced run-off and soil erosion.

Secondary species with firewood/biomass potential: in very few stands Quercus sp. species are present in amounts enough to provide firewood potential in the mid to long term, so these specific areas need to be identified and mixed forest silvicultural prescriptions need to be implemented, to favor broadleaved species and higher quality firewood.

Natural regeneration: The uniform shelter wood regeneration system has been consistently successful in Turkey in pure stands (Gezer, 1985). In this case, as thinning is conducted previously to prepare the stands for regeneration, two regeneration cuts are proposed.

Forest management model

The general model for Andket forest suggests an even-aged structure with a 60-70 years rotation. Gezer (1985) proposes, for Turkey, a 50 years rotation in good sites, and 60 years in medium to poor. However, the rotation suggested for Andket is increased to 80 years to obtain optimum yield due to the physical protection characteristics of the forest. This would require regeneration of 17 ha/year, or around 170 ha in a planning period of ten years (1,640 ha/80 years).

The suggested thinning sequence and its associated treatment is as follows (Figure 51):

1st Intervention:

In the regeneration stands of 20 years of age (H0 = 10 m), the entry of the forest in pole stage would start the second 20-year period to achieve timber stage and full productive capacity around 35 to 40 years (H0 = 14 m). The treatments during this period include:

- Systematic skidding road opening: This consists of tracks (2.5 m wide) opened for harvesting perpendicularly to the existing forest road (every 10-15 m).
- Thinning from below: This consists in removing the dominated strata classes in the forest leaving 700 -950 trees/ha.
- Low pruning in strategic points: This consists in the pruning of tree branches up to 2 m height.
- Seed trees felling: This consists in the removal of the seed trees remaining from the previous rotation (previous 80 years stands).
- In addition, the thinning is intensified around future promising trees, which are released from competition, even if this implies taking out co-dominant trees.

2nd Intervention:

The treatments in this timber stage to 40 years (H0 = 14 m) include thinning from below and releasing selected promising trees for the future from competition by leaving 400 - 475 trees/ha.

3rd Intervention:

At 50 years of stand age (H0 = 17.5 m), thinning may focus in releasing selected trees from competition in a circular area of influence (a few m^2), leaving the best 125 - 200 trees/ha. Again, treating the rest of the stand will depend on other criteria related to available budget and fire hazard.

4th Intervention:

At the stage of 65 years (H0 = 19 m), the final cut is conducted leaving seed trees (50 trees/ha). In some areas, there may be an intervention at 60 years (4º) and another (5º) at 70 years, for protection reasons, if natural regeneration is compromised. Most trees should be cut before or at 80 years of age maximum with felling expanding over the 20-year regeneration period.

Next thinning sequence:

After this period, the young plants (0-20 years-old) will be sharing regeneration units with the remaining seed trees (10-20 trees/ha). These mature trees can be removed in the next 15-20 years when the first thinning intervention takes place for the next thinning sequence of 60 to 80 years. Removing the mature trees helps in making the next first thinning more profitable.

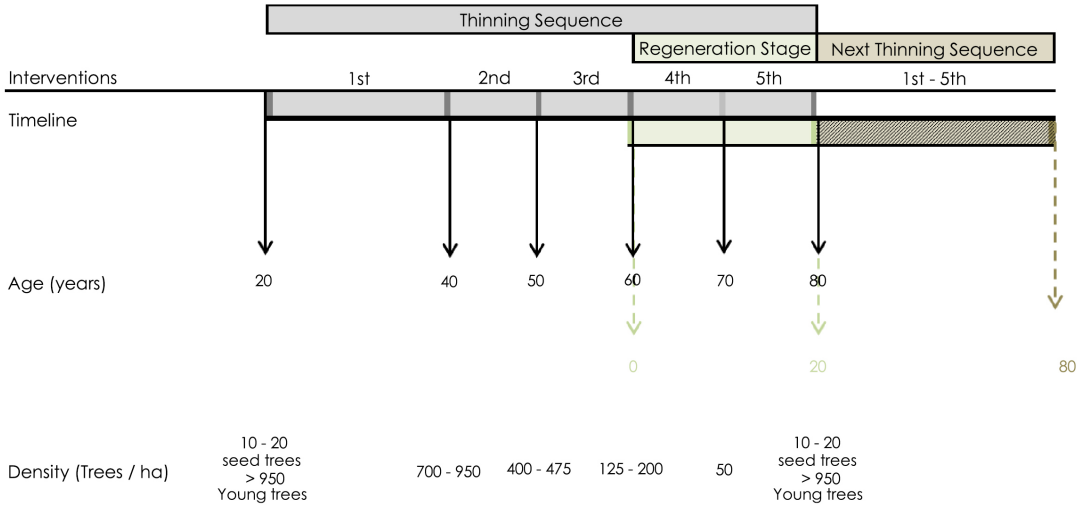


Figure 51. Generic scheme for silvicultural treatments in Andket forest

Adaptation to the management model

This general model needs adaptation to the site conditions. In the best site index areas, the rotation is the lowest (60 years). In the worst site index areas (shallow rocky soil, soil protection stands in steep slopes) the rotation should be extended up to 70 or even 80 years (or be eliminated with no intervention allowed).

Moreover, the first treatment proposed at 20 years of age should be adapted to the current intermediate transitional stages in thick uneven aged stands presenting instability problems (dense stands with thin and high trees), where the proposed thinning might be too intensive. A sudden drop from thousands of trees to 700 trees/ha may prove negative for structural stability. In addition, as there is no certainty that regeneration felling will be allowed under the current legal scenario, and may even not be advisable if wildfires persist, this Plan is based on biomass extraction only from thinning applied to release future trees from competition and general improvement of the forest by cutting damaged, unhealthy, deformed or low-growth, low-quality trees.

Stand development stage (forest type) is identified from inventory data. Accordingly, a specific thinning prescription is assigned based on development stage and density. Prescriptions are adapted to the current status of the stand typologies, which do not cover the range of structures in the general model above. Only the first two stages could be identified in the field. Areas with trees over 40 years tend to have an uneven-age structure (irregular) in Andket, caused by the past lack of treatments under technical criteria.

In general, all treatments should be implemented under the supervision of trained personnel in silvicultural harvesting. Also, pre-thinning tree marking should be done adequately to achieve better implementation of forest goals.

Mapping management units and harvesting blocks

Harvesting blocks to be treated in the next planning period are listed in Table 35 with reference to their location in MUs and forest types. Figure 52 displays their location in Andket.

Table 35. Harvesting blocks location, composition and areas. Slopes are averages for harvesting block

HB	MU	A (ha)	Slope (%)	LULC	Forest typology
1	1	10.32	35	9	Uneven-aged forest
2	2	10.46	30	8	High Pole stage
		6.84	55	8	High Pole stage
3	3	10.46	35	9	Uneven-aged forest
4	5	5.36	35	8	High Pole stage
5	5	2.99	24	7	Low pole stage

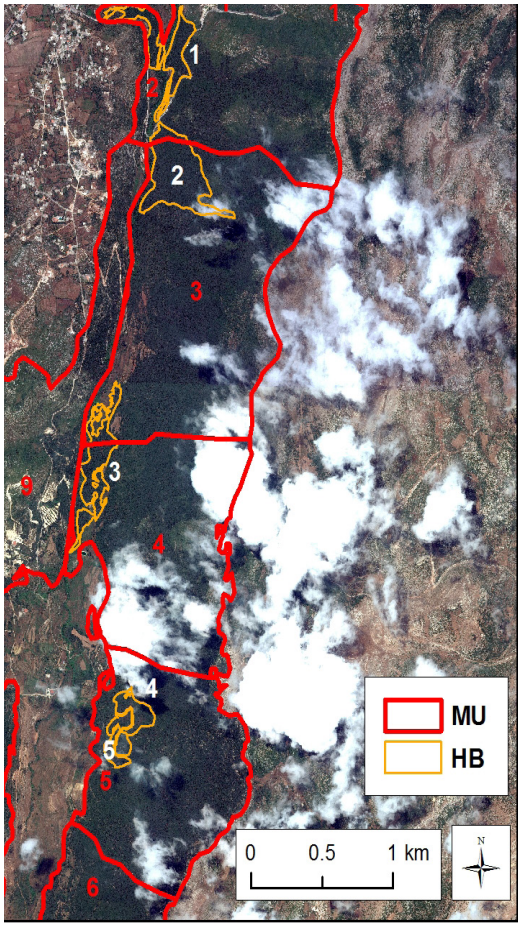


Figure 52. Harvest blocks delimited for the planning period in Andket

Topography is favorable to harvesting in harvesting blocks, as this criteria coupled with access was the principal consideration in defining harvesting blocks for the next planning period (2016-2025). However, as a consequence of the fact that nowadays only the biomass from stands in the 20-50 m buffer area around the few existing forest roads can be harvested, only a very minor part of the total standing biomass can be extracted.

Silvicultural prescriptions by MU

As previously mentioned the proposed silvicultural prescriptions for Andket forest should be adapted to the current conditions. The main criteria which affect the prescriptions per MU are the LULC and forest typology in each unit, in addition to the site index, accessibility, and vulnerability after fire (Table 36).

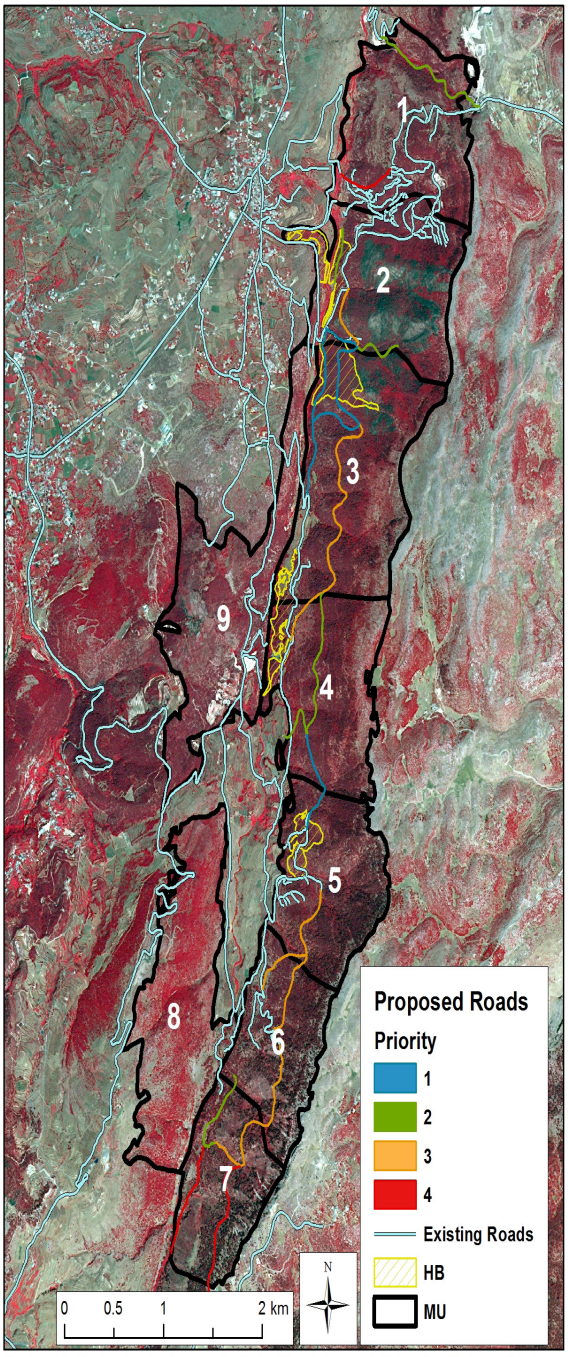
Table 36. Prescriptions per MU based on typology, site index, accessibility, and vulnerability after fire

MU	HB	LULC	Forest typology	Prescriptions by MU	Year of treatment
1	1	9	Uneven-aged forest	THIN + L-PRUNE	2018
				PLANT	2016
				R-OPEN-2	2017
				R-OPEN-4	2019
2	2	8	High Pole stage	THIN + L-PRUNE	2017
				PLANT	2016
				R-OPEN-2	2017
				R-OPEN-3	2018
3	3	9	Uneven-aged forest	THIN + L-PRUNE	2016
				R-OPEN-1	2016
				R-OPEN-3	2018
4	NA	6	Medium-high shrublands with seed trees	PROTECT	2016-2025
				R-OPEN-1	2016
				R-OPEN-2	2017
				R-OPEN-3	2018
5	4, 5	8, 7	High Pole stage, Low Pole Stage	THIN + L-PRUNE	2016
				THIN + L-PRUNE	2018
				R-OPEN-1	2016
				R-OPEN-3	2018
6	NA	8, 9	High pole stage forest Even-aged forest	R-OPEN-3	2018
7	NA	6, 5, 8, 9	Medium-high shrublands with seed trees Low-medium shrublands and thicket stage forest High pole stage forest Uneven-aged forest	PROTECT	2016-2015
				R-OPEN-2	2017
				R-OPEN-3	2018
				R-OPEN-4	2019
8	NA	5	Low-medium shrublands and thicket stage forest	PROTECT	2016-2025
9	NA	4	Low shrublands	PROTECT	2016-2025

** NA: Not Accessible, HB do not exist due to the lack of roads; THIN: Thinning for wood extraction and release of future trees from competition; L-PRUNE: Low pruning up to 2 m for fire hazard reduction; PLANT: Urgent planting of seedlings for regeneration in MU affected by recent fires; R-OPEN: Road opening by priority to increase accessibility of the forest, PROTECT: Protection and preservation applied to forest stands growing on poor sites, shallow soil, rocky stands and steep slope facing unfavorable growth conditions, being not or hardly reachable and sites with high fire risk such as LULC 6 (cleaning and preserving seed trees).*

Accessibility of the forest was assessed from field visits and with the use of satellite imagery. The results indicated difficult accessibility to the different parts of the forest. Accordingly, new roads shall be opened for harvesting purposes. Opening new roads might not be recommended by ecologists, among others. Whether to open or not to open new roads shall be extensively discussed, argued, and agreed on among relevant stakeholders. However, it is essentially important to note that any opening of a new road should be carefully conducted with the main purposes of serving future harvest plans and possibly future firefighting. For protection and fire prevention purposes, public accessibility on the news roads should be closely controlled and monitored by the Municipality. Such control and monitoring require a long term commitment from the Municipality according to which, permits and licenses to opening shall be released by relevant authorities.

Figure 53 shows the existing roads versus the proposed roads by priority. These roads connect with those proposed for Andket's harvesting blocks. Each road has a priority rating from 1 to 4 according to feasibility (topographic conditions) and standing volume to be accessed. Forest roads are 6 m wide for representation purposes, but width could vary based on local topographic conditions (i.e. slope, vegetation cover, risk of soil erosion, etc.). With the available Digital Elevation Model (DEM) it would be preferable not to risk advancing numbers for costs. Such task requires a specific project with better topographic information.



Produced by the Biodiversity Program, Institute of the Environment, University of Balamand, Lebanon in partnership with University of Lleida, Spain
April 2015

Figure 53. Proposed forest road network for optimal production of biomass in Andket forest

It should be noted though, that the harvesting blocks and related treatments that might be established after the opening of the proposed new roads during the period of the management plan are not taken into consideration in the prescriptions. The decisions about these activities should be taken during the actual implementation of the harvesting plan.

As observed in the field, there is a general lack of natural regeneration after fires at least in the North. Accordingly, it is proposed to plant in areas within MUs identified as requiring urgent planting: areas with recent fires in MU1 and MU2, located in the central or core burned area (difficult to regenerate naturally for lack of seeds in close vicinities). Good technical advice on seed production in nursery, planting and tending Pinus brutia is given in Gezer (1985).

Another characteristic taken into consideration is the presence of several ***Quercus*** species (and other broadleaves) in the forest. These should be protected from treatments (i.e. for conservation purposes) and promoted whenever possible (MU 8 and 9). Also, it is worth noting that the calorific power of Quercus is much higher than pine. As such Quercus species can be the subject of improvements and incorporation into a sustainable cutting cycle in the future. The usual structure for this goal is a coppice, which could be accepted in the near-medium term with rotation 20 years, but in the long term, high forest structures and more mixed forest should be preferred/favored.

Silvicultural prescriptions by harvesting block

Given that regeneration may not be a specific goal for the next ten years, and taking into account the constraints in forest accessibility, the spatiotemporal organization of treatments does not aim to establish a sustainable cutting/regeneration cycle in Andket following the general model. However, it is currently aimed at responding to the biomass input needs of briquette production of plant to be established in Andket, through creating a culture for silviculture treatments and management practices, and aiding in capacity building of the forest administration and workers. Harvesting the accessible stands with the higher stocking measured is expected to operationally reduce the thinning/pruning period to three years. Consequently, prescriptions are given for harvest blocks in the next planning period, and not for all of the forest.

Accordingly, Table 37 lists the treatments planned (i.e. thinning), prioritized and summarized yearly in Annex XII including the relevant biomass variables.

Table 37. Silvicultural prescriptions by harvesting blocks

HB	A	Year	Prescription	Source: Martinez et al 1993			Source: Montero et al 2005				
			E (%)	V (m^3)	E_V (m^3)	B_{green} (T)	B_C (T)	B_F (T)	E_B_C (T)	E_B_F (T)	E_B_T (T)
1	10.32	2018	15	1226	183.9	165.5	505	244	76	37	112
2	10.46	2017	20	1551	310.3	279.2	652	319	130	64	194
	6.84	2017	20	1014	202.8	182.6	426	209	85	42	127
3	10.46	2016	15	1681	252.1	226.9	1017	454	153	68	221
4	5.36	2016	20	1145	228.9	206.0	421	213	84	43	127
5	2.99	2018	20	355	71.0	63.9	186	91	37	18	55

Where,

HB *harvesting block*

A *Area in hectares*

E (%) *Percentage to be extracted*

V (m^3) *timber volume over bark in the HB*

E_V (m^3) *extracted timber volume with bark*

B_{green} (T) *green biomass*

B_C (T) *coarse dry biomass in the HB (12% water content)*

B_F (T) *fine dry biomass in the HB (12 % water content)*

E_B_C (T) *extracted coarse dry biomass in the HB (12% water content)*

E_B_F (T) *extracted fine dry biomass in the HB (12% water content)*

E_B_T (T) *E_B_C (T) + E_B_F (T)*

1 m^3 over bark = 0.9 T green= 0.6 T dry (12%)

Pruning may be carried out on future trees at the same time as thinning for release from competition, but amounts or residues from this source are expected to be negligible. Pruning height should be enough to reduce fire hazard, but not too high to reduce costs. Shoulder height to facilitate pruning with chainsaw should be favored. Cut should be executed as close to the trunk as possible without damaging the stem, making sure no more than 1/3 of the crown is removed. Diameters inferior to 10 cm are not allowed to be pruned.

Logistics on how to minimize disturbance to forests

Disturbance by exploitation can only be expected in the scarce areas accessible for biomass harvesting.

Potential locations for processing harvested products are constrained by topographic factors. Reunion areas (or loading yards) should be placed by the paved roads in flat areas where forest roads converge, and are indicated by UTM coordinates in Annex XII with Prescriptions for each harvest block.

Given that whole Pinus brutia trees of small-medium diametric class are expected to be processed, the ideal location for processing would be at the reunion areas, where forest residues would be chipped and loaded on trucks to the carried to the stocking yard of the briquette plant. Whole trees should be collected according to the operational infrastructure schematically described in Figure 54. This structure would diminish costs and improve safety for forest workers by reducing operations in difficult terrain.

Most of the trees processed will come from the hauling tracks/skidding roads (2.5 m) opened for harvesting perpendicular to the forest road (every 10-15 m). Trees over 15 cm diameter may need some cross-cutting on site to transportable pieces before hauling to the forest road, in order to collect packages of 5-10 trees (or pieces) easily handled by the tractors. Felling should be planned in an oblique position (directed felling) to the collection path (not in the direction of maximum slope), to diminish soil damage and erosion, avoiding regeneration clusters or protected species. Whenever operations are in the vicinity of a water course or ravine, care should be exerted to protect riparian or broadleaf species.

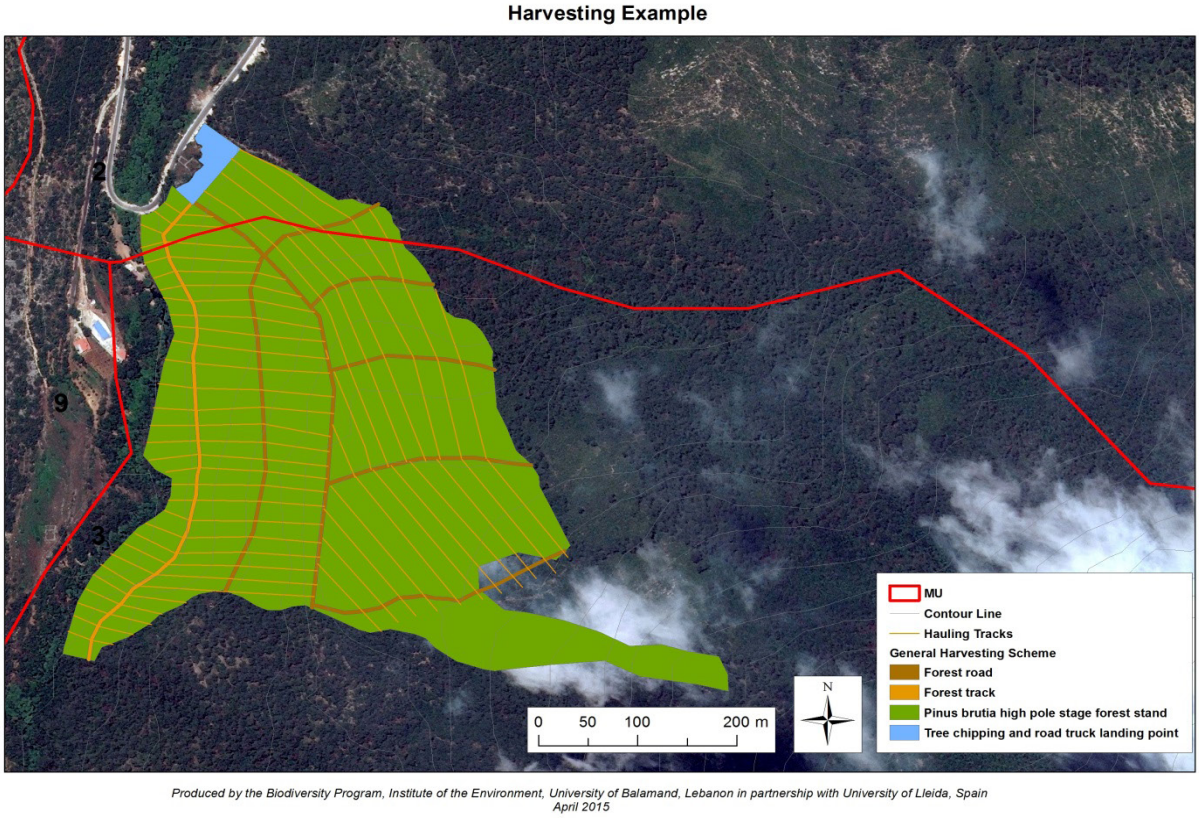


Figure 54. Schematic flow of harvesting operations in Andket

The harvest procedure is different in areas over or below 15% slope, requiring different logging equipment. In flat areas <15% slope wheeled tractor haulage is possible from the felling site to the reunion area or loading yard. The tractor carries a grip tong for the wood. The best technical option for stands over 15% slopes is power cable logging. The track laying tractor carries a winch in this case. Wood is collected with the cable from the felling site/hauling track to the forest road, and then packages are formed and hauled to the loading yard with a wheeled tractor.

The loading yard is the location in which the shredder is placed. If fuel must be provided to the village, this is the point for cross-cutting and piling the desired portion of the total production. The chipper spout could dump directly to the truck box for transport or to the ground. In both cases it would be necessary/convenient to have in the yard a tractor with a derrick tool to manipulate the packages brought by the skidders or hauling tractors. This tool can be sheathed with a cover and be also used to load chips on trucks.

Leaving the trees for just a few days (10-15 days at least) in place (and in winter) before hauling does not raise significantly fire hazard, but allows water content to drop to make transport more efficient, and needles dropping in the site are good for soil fertility.

Equipment and labor requirements

No previous data is available on existing equipment and labor qualification for the required treatments. The Municipality of Andket and AFDC has undertaken in past years a regular cleaning of the forest bush-layer and floor from dead twigs and plant material near the edges of roads, so some equipment (at least agricultural tractors, chainsaws and trucks) must be available, or can be adapted without undertaking costly investments. In any case, the experience gained is not enough for the technical demands of silvicultural selection of future trees, so specific training is needed. As indicated before, Andket Forest has not been the subject of professional technical forest management plans and there are not management activities other than the fire prevention actions mentioned above. Unsuitable pruning techniques and lack of planning in thinning and cutting are pervasive, but these practices need to change if the forest is to have a future that does not lead to degradation.

Harvesting work schedule

Temporal organization of work is provided in Table 37 above for the period 2016-2018, for each harvest/prescription unit. Treatments in Andket were originally intended to be planned for 10 years, but the analysis of resources available shows that accessible biomass will be finished in three years unless new forest roads are built. Seasonally, we keep legal constraints; all prescriptions/treatments will be executed between September 15th and April 15th.

Harvesting cost estimation and technical resources

Treatments scheduled and the relevant variables for estimation of processing costs for treatments (ha, m^3), and the green biomass to be processed every year (T) in the harvesting blocks were quantified in Table 38. Limited pruning is scheduled always with thinning and restricted to future trees up to 2 m maximum height.

Opening of the forest (i.e. skidding roads or hauling tracks) is required before proceeding with pruning activities. The areas to be opened were therefore estimated considering the percentage of prescribed thinning to take place. The assumption that the remaining area of the five Harvesting Blocks (Table 38) are to be pruned was considered, leading therefore to a total area to be opened of a range of 8.25 hectares and a total area to be pruned of 38.18 hectares within the coming three years, (i.e. 2016-2018).

Table 38. Thinning and pruning in the identified Harvesting Blocks

Harvesting Block	Area (ha)	Thinning (%)	Areas to be opened/ thinned (ha)	Assumption- Pruning (%) (=1-thinning)	Areas to be pruned (ha)	Density (trees/ ha)	Number of trees to be pruned
1	10.32	15	1.55	85	8.77	839.89	7,368
2	10.46	20	2.09	80	8.37	1,532.57	12,825
2	6.84	20	1.37	80	5.47	1,532.57	8,386
3	10.46	15	1.57	85	8.89	839.89	7,467
4	5.36	20	1.07	80	4.29	1,532.57	6,572
5	2.99	20	0.60	80	2.39	1841.1	4,404
Total			8.25		38.18		47,021

Opening/thinning activities

Considering a labor cost of 2400$/ha for forest opening (CDR/GFA/EU 2013), an average total labor cost of 9.9 Million LBP per year (Table 39) is obtained for Andket forest (i.e. opening for 2016, 2017 and 2018).

Table 39. Labor cost for opening during the first three years

Total areas to be opened/ thinned during the first 3 years (hectare)	Labor Costs for Opening (LBP/ha)	Total cost of opening (LBP) for the first 3 years	Total cost of opening (LBP) per year
8.247	3,618,000.00*	29,837,646.00	9,945,882.00

** CDR/GFA/EU (2013): Labor cost for opening forests: 2400 $/ha*

It should be noted that the cost for opening new roads cannot be estimated and the financial analysis for its related activities should be elaborated separately during the implementation of the harvesting plan.

Pruning activities

The costs of pruning per hectare were then evaluated. Three methods were used based on availability of data for comparative purposes.

Method 1: Based on unit costs calculated from total costs of pruning (i.e. ranging between 66.657 and 87.488 Million LBP) and total pruned area (210.9 ha) obtained for Bkessine (Table 40).

Table 40. Pruning costs based on Bkessine pruning costs calculations

	Cost (LBP) per hectare pruned	Total cost of pruning during the first three years	Total cost of pruning (LBP) per year
Lower limit	3,159,824*	120,651,559	40,217,186.35
Higher limit	4,147,269*	158,355,171	52,785,057.08

** Obtained from Bkessine calculations of costs for pruning (Total pruning costs/Total pruned area in hectare)*

Method 2: Based on unit costs (LBP/ha) for Fire Prevention by site cleaning (Table 41).

Table 41. Pruning costs based on site cleaning indication

Total areas to be pruned during the first 3 years	Labor Cost (LBP/ha)	Total labor cost for site cleaning (LBP) during the first 3 years	Total labor cost for site cleaning (LBP) per year
38.18	3,376,800.00*	128,936,354.40	42,978,784.80

**(CDR/GFA/EU 2013): Labor cost for Fire Prevention by Site Clearing: 2240 $/ha*

Method 3: Based on adjusted numbers obtained from field visits in Bkessine, to take into account a higher number of trees pruned per day (since pruning is only done at the understory level).

The total number of trees to be pruned during the next three years was estimated to 47,021 trees. Considering that in Andket, pruning will take place only at the understory level, only costs of pruning understory, cleaning, and transportation were taken into account. Accordingly, a total cost of 80,000 LBP per day per team of two workers (instead of three in the case of Bkessine) was estimated (Table 42).

Table 42. Total cost per team of two workers

	Average Cost per day (LBP)
Pruning understory and cleaning	40,000
Separation and loading into trucks	40,000
Total per day per team	80,000

In addition, an assumption that the number of trees pruned in Andket per day and per team could be as twice as what it was in Bkessine (since pruning is taking place only at the understory level in Andket) was taken into account. The total costs were therefore calculated (Table 43).

Table 43. Total costs of pruning, cleaning, and loading

	Number of trees pruned per day	Cost per tree (LBP)	Total costs of pruning/ cleaning/loading into trucks over a period of 3 years (LBP)	Total costs of pruning/ cleaning/loading into trucks per year (LBP)
Small	50*	1,600.00	75,234,107.57	25,078,035.86
Medium	20*	4,000.00	188,085,268.92	62,695,089.64

**Assumptions based on expert judgment*

The different methods were tested due to the diversity of data sources and assumptions taken. The three methods led to an average cost for pruning in Andket ranging between 42.9 to 46.5 Million LBP per year.

Planting

Burned areas without signs of natural regeneration should be regenerated artificially in the next ten years (core burned areas), requiring 2,720 seedlings per year (17 ha, 1,600 trees/ha, 2.5x2.5 m layout). In 2025, the burned areas selected in MU1 and MU2 should be evaluated for regeneration success and re-planting can take place where required.

Two scenarios were also considered for Andket. The first one included the costs of purchasing the seedlings, and the second one excluded these costs. The unit costs, namely cost of one seedling, cost of labor for the preparation of land, and cost of labor for planting one tree, are those used for Bkessine, leading to total costs of 13.08 Million LBP per year for scenario 1 and 9.4 Million LBP per year for Scenario 2 (Table 44).

Table 44. Total costs of planting seedlings

	Total Costs (LBP over a period of 10 years)				
	Seedlings	Labor for the preparation of land (digging holes)	Labor for planting	Total cost over a period of 10 years	Total cost per year
Scenario 1 - Including cost of seedlings	36,667,776.00	75,678,215.47	18,436,160.00	130,782,151.47	13,078,215.15
Scenario 2 - Excluding cost of seedlings	-	75,678,215.47	18,436,160.00	94,114,375.47	9,411,437.55

It should be noted that for all financial calculations, the current cost was applied all over the planning periods (i.e. 2016 to 2018 and 2016 to 2025), without taking into account inflation rate.

Finally, equipment such agricultural tractors, chainsaws, and trucks must be available, or can be adapted without undertaking costly investments.

Procedures for monitoring and evaluating the harvest plans

Controls for completely treated harvesting blocks are easier than for small areas or individual trees, hence the planning matches complete harvesting blocks with specific years of treatment. Table 45 shows the expected outputs in terms of biomass extracted every year if treatments in the harvesting blocks are executed as planned for 2016-2018. Values used for this table are based on minimum estimates that remove only an estimated 10-25% in basal area (BA) in thinning, so supply to the briquette plant for 500 T/year seems not feasible if new infrastructures are not built. The total biomass extracted if the proposed roads are built by priority show that the supply for the briquette plant will be sufficient for the years 2016 to 2018. In year 2019, the supply is not enough unless new harvesting blocks around the newly opened roads are established. This assumption is not considered in the scope of this management plan and estimates will depend on the future implementation of the prescriptions.

Table 45. Biomass production by year in the Plan

Processing Year	Biomass from HB (T)	Biomass from proposed roads opening (T)*	Total Biomass in T (HB+Roads)
2016	432.9	165.14	598.04
2017	461.8	149.761	611.561
2018	229.4	261.916	491.316
2019	0	77.917	77.917

** The minimum biomass that could be extracted from the opening of proposed roads (Priority 1 to 4) between 2016 and 2019*

Biomass production controls are not proposed in the field, but upon delivery to the briquette plant, where the processing takes place and where measures for weighting can be implemented, and probably will in the daily operation of the plant. Currently, firewood production is not controlled or evaluated, but pick up of this product is proposed to be located in the reunion areas. Firewood production can be estimated, accordingly, from load carried by a truck.

It is a very important commitment to record keeping in a book of the forest as we could not locate accurate data on previous years on harvest, costs, yields, or locations treated before.

Barriers and constraints (challenges) for further development

The main technical constraint in Andket is accessibility to the forest. The proposed forest road network Figure 53 (Annex XIII) should be funded in a separate project according to the recommendations and terrain volume estimations and priorities.

Forest age classes are distributed in a range wide enough that sustainability should not be an issue and diversity is quite high. Site quality is also diverse and dependent on topographic position, but environmental factors (climate, soils) indicate prospects are good for this forest. The current state of the forest admits improvement of forest stand structures through professional forest management, but the know-how is not in place.

Machinery adapted to forest operations may not be available, or require investment.

Improvements in the forest require that the management plan will be implemented within an agreement with the Ministry of Agriculture and under the supervision of the forests center and forest guards of the Ministry. As some actions/recommendations in this Plan are controversial or down right illegal, acceptance by the authorities is needed. Removing low-quality, slow-growing, damaged or defective trees, for example, may encounter legal or administrative barriers.

List of Annexes (Andket)

Annex VIII. Maps of Management Units and Harvesting Blocks

Annex IX. Completed field forms for the 26 plots in Andket

Annex X. Forest Inventory LULC detailed by diameter class and species

Annex XI. Forest inventory Forest characteristics by management unit detailed by diameter class and species-Total values

Annex XII. Prescriptions and treatments by Harvesting Blocks

Annex XIII. Existing and proposed forest road network

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